TECHNOLOGY FOR CONSTRUCTION INDUSTRY OF BANGLADESH

BY

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A project submitted to the Department of Industrial & Production Engineering, Bangladesh University of Engineering & Technology, Dhaka, in partial fulfillment of the requirements for the degree of

MASTER OF ENGINEERING
IN
ADVANCED ENGINEERING MANAGEMENT (AEM).

APRIL 18, 2004

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BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
DHAKA-1000, BANGLADESH
TECHNOLOGY FOR CONSTRUCTION INDUSTRY OF BANGLADESH

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DECLARATION

I hereby certify that the research work reported in this project has been performed by me and that this work has not been submitted elsewhere for any other purpose without written permission from the author.

April, 2004

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ACKNOWLEDGEMENT

The author wishes to express his deepest gratitude to Dr M. Anwarul Azim, Professor, Department of Industrial and Production Engineering (IPE), BUET for his continuous guidance, invaluable suggestions and affectionate encouragement in many stages of this study.

This author is grateful to M. Ahsan Akhtar Hasin, Associate Professor, Department of Industrial and Production Engineering (IPE), BUET for rendering his helping hands during the course of this study.

This author wishes to express his profound gratitude to Dr. Mahiuddin Ahmed, Professor and previous Head, Department of Industrial and Production Engineering (IPE), BUET for the interest taken by him in this research and for his miscellaneous help.

This author is also grateful to Design Planning and Management Consultants Ltd. for their helping hands during the course of this study.

Last but not least the author owes his deep sense of gratitude to his only tiny daughter and family members for spends time during project work.

Author
ABSTRACT

The *Indus Valley* civilization shows that, Indian sub-continent had a leadership in the advancement in construction Technology and Industry over the world. But unfortunately this part of the sub-continent especially Bangladesh could not cope with the modern technological advancement.

Construction technologies can, on the basis of their content of labor and equipment, be classified as equipment intensive, labor intensive and labor based technology. In recent years, technological innovation in design, analysis, construction materials, construction methods, etc have resulted in significant changes in construction industry. Computer aids have improved capabilities for generating worth designs, reducing the time requirement to produce alternative designs to ensure safety with economy. New technologies not only have enhanced the quality of construction but also have shortened the time for shop fabrication and field erection. Construction methods have advanced through various stages of mechanization and automation, including the latest development of construction robotics. That means trend is advanced technology.

In this study, 25 numbers of six to nine storied buildings and 4 numbers of twenty to thirty storied buildings have been studied. It has been observed that, the construction industry in Bangladesh dominated by labor-intensive technology, lower grade material and primitive construction procedure. In most of the cases 29% more cost involvement has been observed. These made construction industry of Bangladesh an inefficient one. Use of high quality material easily saves huge monetary loss in this sector. This will require active participation of Engineers in design house and in field. Further detail study may enhance this fact elaborately.

Different sizes 10 numbers building of different excavation depth have been studied. Of these considering PWD standard rate of works; it has been observed that for deeper excavation, excavator or equipment intensive technology is cheaper than labour intensive excavation. For ending conclusion of equipment intensive excavation require, further detailed investigation.

Bangladesh could regain leadership in the construction industry, over the world through accepting and participating in the advancement of the modern technologies. The scopes are waiting ahead. Entrepreneur, especially the Engineers should come forward to take the challenge to advance Bangladesh in that direction.

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<th>Full Form</th>
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<tbody>
<tr>
<td>ADP</td>
<td>Annual Development Program</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing Material</td>
</tr>
<tr>
<td>BS</td>
<td>Bangladesh Standard</td>
</tr>
<tr>
<td>BUET</td>
<td>Bangladesh University of Engineering and Technology</td>
</tr>
<tr>
<td>GATS</td>
<td>General Agreement on Trade &amp; Services</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>kip</td>
<td>Kilo-Pound</td>
</tr>
<tr>
<td>ksi</td>
<td>Kilo-pound per Square Inch</td>
</tr>
<tr>
<td>PC</td>
<td>Personal Computer</td>
</tr>
<tr>
<td>psi</td>
<td>Pound per Square Inch</td>
</tr>
<tr>
<td>PVC</td>
<td>Poly Vinyl Chloride</td>
</tr>
<tr>
<td>PWD</td>
<td>Public Works Department</td>
</tr>
<tr>
<td>QC</td>
<td>Quality Control</td>
</tr>
<tr>
<td>R &amp; D</td>
<td>Research &amp; Development</td>
</tr>
<tr>
<td>RC</td>
<td>Reinforced Concrete</td>
</tr>
<tr>
<td>RCC</td>
<td>Reinforced Cement Concrete</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>WTO</td>
<td>World Trade Organization</td>
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</table>
1.1 Development of Construction Technology

Building is the earliest form of technology in civil engineering construction. From the most primitive times, humans required protection from the wild animal, elements of nature, changing seasons and predators, in natural shelters such as caves and rock overhangs.

Step by step, they learned to improve their caves with inlaid stone floors, walls at the entrances and fireplaces. Ultimately they began creating entirely new habitats in locations that had no natural shelter.

Shelters built from natural materials indicate that they had knowledge of the stress, strain and insulation properties (heat, cold and water-proofing) of the materials used. The use of hand-made bricks or stone blocks indicated knowledge of properties such as compression forces. The symmetrical shapes of the designs indicated the knowledge and application of the principles of geometry.

Most communities had their own distinctive styles for building their houses and archaeologists have uncovered many examples through the ages [Shown in Fig. 1-1(a) to Fig. 1-1(e)]
The building trade is the earliest form of civil engineering construction. Up to 13th century building technology in the sub-continent fell under three category (a) Thatchery and mud houses made of thatched roof of bamboo, straw, grass reed etc (b) stone masonry which included hewing, laying and carving of stone and (c) Brick masonry construction consisting of lime-surki mortar in the city areas. Between 13th and 18th century the feudal monarchs and the land lords constructed monumental buildings. After the industrial
revolution in the 18th century, construction of factory buildings, labor sheds, warehouse houses etc became the major construction activities. With the invention of the steam engine in the 18th century development of railways started. Besides, the construction of roads, ports and harbors, inland and offshore navigation developed simultaneously after the Second World War reconstruction of the war ravaged infrastructure brought a boom in the civil engineering construction. Civil engineering also has attained modernization an eventually in the seventies the development of chips and micro chips and the high capacity single chip microprocessor made possible the development of the micro computers. The computer software technology has also developed very fast simultaneously. The development of the optical fiber and the satellite technology has made a revolution and the internet has brought the information technology to a stage which was unimaginable even a decade ago. As result knowledge based industries now dominate over the previous machinery based industries. Traditional construction industry as gradually becomes obsolete and ineffective worldwide in these high tech eras. This new situation put construction industry a new challenge.

In modern times the civil engineers built dams, sluices, regulators, barrages, pump houses and power generation and many other structures which were believed to be impossible to construct. Gigantic modern off-shore structures are now built which go to several hundred meters below sea level. In the field of bridge construction enormous progress have been achieved. Bridges has now become relatively cheap and can be built in extremely short time. The most ambitious bridge development ever realized is certainly the Akashi-Kaiko Bridge in Japan with a span of 1990 meter. This gigantic endeavor at the early age where only possible due to very sophisticated and heavy erection equipment developed. The successful construction of channel tunnel, Bull twinkle (492 m world's tallest offshore platform), Louisianan offshore oil port (supertanker unloading capacity of 100000 barrel an hour), Kansai international airport (a port reclaimed from sea bed containing extremely soft soil), testify to development capability of the civil engineering profession in modern times. it will not be out of place to mention that during the sixties intensive urbanization in many developed countries saw the
spectacular revolutionary concepts such as wall frame interaction, tube-in-tube bundle tubes, diagonally braced frame and composite construction pioneered the high rise growth. Developments of intelligent buildings that can respond to earthquake and fire hazards are in the making.

In recent years (Information age), technological innovation in design, materials and construction methods have resulted in significant changes in construction costs. Computer aids have improved capabilities for generation quality designs as well as reducing the time required to produce alternative designs. New equipments and materials not only have enhanced the quality of construction but also have shortened the time for shop fabrication and field erection. Construction methods have gone through various stages of mechanization and automation, including the latest development of construction robotics.

The Global Trend

Competition in global market for better & economic building construction is increasing day by day. Construction organizations are realizing that responsiveness to market demands and adaptability to changing condition. Competitive prices are the hallmarks of successful enterprise. Therefore every construction organization wants to lower the cost by alternate design, interchanging material strength & type, using modern construction methods and proper management. So construction world is going for new technology and saving both time and cost.

The Bangladesh Context

Bangladesh has come a long way since its independence. But a very few organizations have adopted new construction technology and ability to build high strength material with quality. After 2004 due to WTO and GATS Bangladesh market has to be made open to outside countries and most of the organization will face difficult challenges from the competitors of other countries. To face this challenge effectively, construction organizations need
to be more responsive to market demands, lower the prices by choosing proper construction technology in all stages of construction as well as improve quality of material. If construction organizations of Bangladesh will able to qualify with other countries in competition they would have to opportunity to work abroad.

Bangladesh is one of the least developed countries in the world. Regrettably in Bangladesh most of the construction methods and design are oriented by conventional method. Though volume of building construction is large, but modern construction method and equipment facilities in most of the cases are absent. Only a small number of projects have been done or ongoing with theses modern facilities. Remarkable new and high strength material are also not using in Bangladesh. Only in some national bridge/road construction project, modern equipment and material were used in Bangladesh. Due to absent of new and high strength materials, new technologies, new equipments, quality as well as efficiency of building construction are very poor.

1.2 Objective of the Project

Bangladesh is one of the least developing countries. Contemporary construction technology with high strength materials are not often using in building construction sector. The objective of this study is, to find out what type of technology and materials are being using for building construction. In addition to find out, if better technology is available why, these are not being accepted at present in construction sector of Bangladesh.

Specific objectives of this study are:

- To study the exiting technological parameters in present day building construction in Bangladesh
- To study the economy of scale and factors as they relate to-
  (a) Humnware
  (b) Infoware and
  (c) Hardware
1.3 Methodology

Methodologies used in this study are followings:

I. Study of the literature to identify the contemporary technology in building construction in developing NIC and developed economies

II. Study of the local documents and of field data to find the status of contemporary technology in the building industry in Bangladesh

III. Study the economy of scale and contemporary technology as they relate to humnware, infoware and hardware.
CHAPTER 2

TECHNOLOGIES IN CONSTRUCTION INDUSTRY

2.1 Introduction to Technology in Construction Industry

McGraw Hill Encyclopedia Defines Technology as¹

Technology is closely related to science and engineering. Science deals with human's understanding of real world around them – the interesting properties of space, matter, energy and their interactions. Engineering is the application of objective knowledge to the creation of plans, designs, and means for achieving desired objectives. Technology deals with tools and techniques for carrying out the plans.

Construction Technology

Basic design and construction topics which include both field and office activates which facilitate problem definition, evaluation, solution, and communication, i.e. design electives, electrical, equipment, estimating, formwork, mechanical, quantity surveying, rigging, scaffolding, scheduling, shop drawings, site planning, surveying, takeoff, utilities.²

Construction industry undoubtedly is the backbone and propelling force behind our progress. It has the potential to contribute to people's lives in many ways. This needs high skill, dynamic leadership, broad vision, great courage, latest technology and communication system.

Modern science and technology have provided many useful tools like computers-CPM-PERT-most productive and efficient machines, financial management procedures and many others. But all these become redundant and unproductive when these sophisticated and efficient tools are worked by green and inexperienced hands, who lack the basic ingredients of work culture, dedication and courage and people who are not imaginative and innovative.
2.2 Construction technologies on the basis of labour and equipment

Construction technologies can, on the basis of their content of labour and equipment, be classified as:

- Equipment Intensive
- Labour based and
- Labour Intensive Technologies.

The choice of the technology may affect the overall cost, the overall duration of the construction, and the overall quality of the asset. Some works allow only one type of technology, while others can be done in various ways. Graphically equipment intensive, labour intensive and labor based technologies are shown in below

**Potential shift in labour contents by using labour-based methods**

<table>
<thead>
<tr>
<th></th>
<th>Labour</th>
<th>Equipment</th>
</tr>
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<tbody>
<tr>
<td>Equipment Intensive</td>
<td>![Diagram]</td>
<td></td>
</tr>
<tr>
<td>Labour Based</td>
<td>![Diagram]</td>
<td></td>
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<tr>
<td>Labour Intensive</td>
<td>![Diagram]</td>
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</table>

2.2.1 Equipment Intensive Technology

Equipment intensive technology is defined as the combination of labour and equipment in which most work is done by labour-replacing equipment, supported by a small labour force. Although the technology might be appropriate in circumstances with high wage levels, low labour availability and high skill levels, its application is often ineffective at local level where individual projects are relatively small and dispersed over a large geographical area.
2.2.2 Labour Intensive Technology

To avoid a common misconception, it is important to distinguish between labour based methods, and labour intensive methods. In contrast with labour based technology, labour intensive approaches seek to maximize employment with a minimum use of mechanized equipment, often at the expense of cost and quality.

2.2.3 Labour Based Technology

In selecting the most appropriate technology, it is however important that, irrespective of the type of technology, resources is used efficiently, quality standards are maintained and time limitations are observed. For these reasons, labour based technology has been developed to maximize opportunities for the employment of labour (skilled and unskilled), while supported by light equipment, under strict conditions of cost competitiveness, acceptable engineering quality standards, and timely implementation. Labour based work methods are competitive only if these conditions are met and can then provide a lasting alternative to traditional equipment-intensive construction methods.

2.3 Software Technologies

Normally software means the written instructions, executed by some hardware, i.e. Programs that are needed to run for execution and manage the computer and those, which are used to solve the problem \(^{(1)}\). The Software technologies have three subdivisions, which are

- Manpower (Humnware)
- Information (Infoware)
- Organization (Orgaware)

2.3.1 Manpower (Humnware)

We know manpower (humnware) is the person-embodied, component of technology \(^{(1)}\). For construction works require different types of personal but most of them require technical background. Different disciplined engineer, site engineer, supervisor, foreman, rod binders, mason, skilled labour, helper,
carpenter, sanitary technicians, electrical technicians and other personal are the humanware.

Productivity in construction is often broadly defined as output per labor hour. Improvement of labor productivity should be a significant activity in building construction. In construction works vigorously pursue the efficient utilization of labor. So improvement of personnel related to this field is a vital factor of construction industry.

2.3.2 Information (Infoware)

Information (Infoware) is usually the document-embodied form of technology. This includes the specifications, market database for materials, theories, charts, database, drawing, codes, books, journals, catalogs and other documents. Requisition and supply management work(s) are also included in infoware. Infoware constitute a crucial part of construction industry. For construction works, every step is related to infoware. Proper constructions need accurate material specification guided by the code(s). Proper information is the key factor of any construction project.

2.3.3 Organization (Orgaware)

Within a framework of the Organization (Orgaware), Manpower (Humnware), Information (Infoware), and Hardware technologies work. Organization techniques, principles, practices and arrangements that govern the effective use of technology by humanware. This includes construction planning, project management, QC, safety, R & D.

Organizational systems play the key role in construction industry. Both the success and failure of construction works widely depends on organization. An organization system includes Organization structure, organization design, human resource policy and practice, organization culture, work stress, etc. Common organizational structures available in construction industries are—

- Project organization
- Matrix organization
- Line and staff organization
2.4 Hardware Technology

Modern construction, especially for large projects, has grown in complexity due to size, cost and speed of construction. Construction equipment is an important resource, and its planning assumes vital importance. With the rapidly changing technology, both in design and construction areas, contractors are now shy of making heavy investment in heavy equipment. New innovation of construction equipment change the older method of construction method and resultant is quicker and economic construction. Sometimes whole system is enhanced by new innovation. Such as two technological developments namely lift and modern metal frame, removed the prevailing limitations on the height of the buildings. Hardware is object-embodies form of technology \( \text{II} \), such as Construction equipment/machineries, all type of materials, appliances, computer, paper, printer.

The selection of appropriate construction equipment often affects the required amount of time and effort and thus the job-site productivity of a project. It is therefore important for site managers and construction planners to be familiar with the characteristics of the major types of equipment. Various types and important works are involved for construction industry. Such as excavation loading, compaction and grading, drilling and blasting equipment, lift and erecting machineries, mixing, construction tools and other equipment. Different types of work require different type of hardware and technology.
Selection of most suitable and available equipment for a particular project is a frequent problem for contractor. Owner, contractor and even the engineers of our country are going for traditional method and material. Sometimes, due to old technique and traditional material huge financial loss is the result.

Money spent for equipments need to be considering as an investment, which can be recovered with a profit during the useful life of the equipment.

2.4.1 Excavation

Types of equipment which are used to excavate earth and related materials are known as excavator. Excavation equipment includes the following machines:

1. Power shovels
2. Backhoes
3. Draglines
4. Clamshells and cranes
5. Trenching machines
6. Wheel-mounted belt loaders

Crane-shovel consists of three major components.

- A carrier or mounting, which provides mobility and stability for the machine.
- A revolving deck or turntable, which contains the power and control units.
- A front-end attachment, which serves the special function in an operation.
Fig. 2-1 Excavation Equipment
g
d (a) Shovel
(b) Shovel
(c) Draglines
d (d) Pile Driver
e (e) Cranes
(f) Clamshells
g (g) Hawk-Bulk Waste
(h) QM-Quick Mount
(i) Off Highway Roll-Off
(j) Hook Lift
(k) Container Carrier
(l) Roll-Off Trailers Carrier
The type of mounting for all equipments (hardware) in the above figure is referred to as crawler mounting, which is particularly suitable for crawling over relatively roughed surfaces at a job site. Other types of mounting include truck mounting and wheel mounting, which provide greater mobility between job sites, but require better surfaces for their operation. The revolving deck includes a cab to house the person operating the mounting and/or the revolving deck. In the above figure a crane with hook, clamshell [Fig.2-1(f)], dragline [Fig.2-1(c)], backhoe, shovel[Fig.2-1(a), (b)], pile driver[Fig.2-1(d)] and other excavation equipment are shown.

A tractor consists of a crawler mounting and a non-revolving cab. When an earth-removing blade is attached to the front end of a tractor, the assembly is called a bulldozer. When a bucket is attached to its front end, the assembly is known as a loader or bucket loader. There are different types of loads designed to handle most efficiently materials of different weights and moisture contents.

Scrapers are multiple units of tractor-truck and blade-bucket assemblies with various combinations to facilitate the loading and hauling of earthwork. Major types of scrapers include single engine two-axle or three-axel scrapers, twin-engine, all-wheel-drive scrapers, elevating scrapers, and push-pull scrapers. Each type has different characteristics of rolling resistance, maneuverability, stability, and speed in operation.

2.4.2 Compaction and Grading

Compaction, grading and soil stabilization are the works of same category and these are interrelated. Many soils are subject to differential expansion and shrinkage when they undergo change in moisture content. If pavements are to be constructed on such soils, it is highly desirable to stabilize them to prevent or reduce the change volume in order to protect the pavements from excessive damages.

Stabilizations may be applied to a soil in its natural position or as it is placed in a fill. Also, stabilization may be applied to the sub-grade, sub-base, or base material.
Some methods of stabilization are

- Blending and mixing heterogeneous soils to produce more homogenous soils
- Incorporating hydrated lime into soils that are high in clay content.
- Blending asphalt with the soil
- Mixing Portland cement with the soil
- Incorporating various types of slats into the soils
- Incorporating certain chemicals into the soils
- Compacting the soils thoroughly after they are processed

The function of compaction equipment is to produce higher dense soil mechanically. The basic forces used in compaction are static weight, kneading, impact and vibration. The degree of compaction that may be achieved depends on the properties of soil, its moisture content, the thickness of the soil layer for compaction and the method of compaction.

The function of grading equipment is to bring the earthwork to desired shape and elevation. Many soils are subject to differential expansion and shrinkage when they undergo changes in moisture content. Many soils also move and rut when subjected to moving wheel loads. If pavements/buildings are to be constructed on such soils, it is usually necessary to stabilize them to reduce the volume changes and strengthen them to the point where they can carry the imposed load even when they are saturated.

Major types of grading equipment include motor graders and grade trimmers. The former is an all-purpose machine for grading and surface finishing; the latter is used for heavy construction because of its higher operating speed.

Many types of compaction equipment are available, including the following - Towed Sheepfoot [Fig.2-2(a)], Grid Roller [Fig.2-2(b)], Self-Propelled [Fig.2-2(c)], Segmented Steel Wheel Roller[Fig.2-2(d)], Self Propelled Tamping Foot Roller, Self Propelled Vibratory Tamping Foot Roller[Fig.2-2(e)], etc. These are different operating characteristics.
Fig. 2-2 Compaction & Grading Equipment
2.4.3 Drilling and Blasting

Drilling operation used by the construction and mining industries to drill holes in both rock and earth. The task of rock excavation includes loosening, loading, hauling and compacting. The loosening operation is specialized for rock excavation and is performed by drilling and blasting.

Rock excavation is a risky and hard task. Require special equipment and methods for this operation. The degree of difficulty depends on physical characteristics of the rock type which to be excavate. Grain sizes, planes of weakness, weathering, brittleness and hardness of rock strata are the vital factors of rock excavation. The task of rock excavation includes loosening, loading, hauling and compacting. The loosening operation is specialized for rock excavation and is performed by drilling, blasting or rippling.

Major types of drilling equipment are percussion drills, and rotary-percussion drills. A percussion drill penetrates and cuts rock by impact while it rotates without cutting on the upstroke.

Common type of percussion drills includes a jackhammer, which is hand held and others, which are mounted on a fixed frame or on a wagon or crawl for mobility. A rotary drill (Fig.2-3(b)) cuts by turning a bit against the rock surface. A rotary precession drill combines the two cutting movements to provide a faster penetration in rock.

Blasting is performed to loosen rock in order that it may be excavated or removed from its existing position. Blasting requires the use of explosives, the most common of which is dynamite. Generally electric blasting caps are connected in a circuit with insulated wires. Power sources may be power lines or blasting machines designed for firing electric cap circuits. Also available are non-electrical blasting systems, which combine the precise timing and flexibility of electric blasting and safety of non-electrical detonation.

Tractor-mounted rippers are capable of penetrating and prying loose most rock types. The blade or ripper is connected to an adjustable shank, which controls the angle at the tip of the blade as it is raised or lowered. Automated ripper control may be installed to control ripping depth and tip angle.

In rock tunneling, special tunnel machines equipped with multiple cutter heads and capable of excavating full diameter of the tunnel are now available. Their use has increasingly replaced the traditional methods of drilling and blasting.
Fig. 2-3 Drilling & Blasting Equipment [14]
2.4.4 Lifting and Erecting Equipment

Lifting and erecting equipments are used to lift loads and to facilitate the erection of steel building frames.

Derricks are commonly used to lift equipment of materials or building construction. A derrick consists of a vertical mast and an inclined boom sprouting from the foot of the mast. Guys hold the mast in position or stiff legs connected to a base while topping lift links the top of the mast and the top of the inclined boom. A hook in the road line hanging from the top of the inclined boom is used to lift loads. Guy derricks may easily be moved from one floor to the next in a building under construction while stiff leg derricks may be mounted on tracks for movement within a work area.

Horizon boom type tower cranes are most common in high-rise building construction. Inclined boom type tower cranes are also used for erecting steel structure.

2.4.5 Mixing

Mixing concrete by hand is expensive in labour and it is, therefore, not surprising that mechanical mixers have been general use for a great many years.

The object of mixing is to coat the surface of all aggregate particles with cement paste, and to blend the entire ingredients of concrete into a uniform mass; this uniformity must furthermore not be disturbed by the process of discharging from the mixer. In fact, the method of discharging is one of the bases of classification of concrete mixers. Several types exist. In the tilting mixer, the mixing chamber, known as the drum, is tilted for discharging. In the non-tilting type the axis of the mixer is always horizontal, and discharge is obtained either by inserting a chute into the drum or by reversing the direction of rotation of the drum, or rarely by splitting of the drum. There are also pan-type mixers, rather similar in operation to an electric cake-mixer; these are called forced action mixers, as distinct from the tilting and non-tilting mixers which rely on the free fall of concrete in the drum.
In any mixer, it is essential that sufficient interchange of materials between different parts of the chamber takes place, so that uniform concrete is produced.

On a site, there is often a tendency to mix concrete as rapidly as possible, and it is, therefore, important to know what is the minimum mixing time necessary to produce a concrete uniform in composition and, as a result of satisfactory strength.

Concrete mixers are used to mix Portland cement, sand, gravel and water in batches.

There may be occasions when concrete has to be mixed by hand and, because in this case uniformity is more difficult to achieve, particular care and effort are necessary.

A truck mixer refers to a concrete mixer mounted on a truck, which is capable of transporting ready mixed concrete from a central batch plant to construction sites.

2.4.6 Construction Tools and Other Equipment

Concrete can be economically pumped at the rates 15 to 200 yd/hr, for horizontal distances 300 to 3000 ft and vertical distances 100 to 500 ft without staging. [11]

The pumping of concrete is especially advantageous in placements that are physically difficult to approach with ready-mix trucks and show best economy in the range of 20 to 80 yd/hr.

Air compressors [Fig.2-4(a)] and pumps [Fig.2-4(d)] are widely used as the power sources for construction tools include drills, hammers [Fig.2-4(b)], grinders, saws, wrenches[Fig.2-4(c)], staple guns, sandblasting guns, and concrete vibrators. Pumps are used to supply water or to dewater at construction sites and to provide water jets for some types of construction.

Vibrators are used to eliminate entrapped air. Of the several types internal vibrators perhaps the most common one. External vibrator is rigidly clamped to the formwork resting on an elastic support, so that both the form and
concrete are vibrated. Vibrating table can be considered as a case of formwork clamped to the vibrator instead of the other way round, but the principle of vibrating the concrete and formwork together is unaltered. Besides these surface vibrator used for flat plate, electric hammer can be used as a surface vibrator when fitted with a bit having a large flat area. A vibrating roller is used for consolidating thin slabs.

![Fig. 2-4 Construction Tools & Other Equipments](image)

2.4.7 Choice of Equipment and Standard Production Rates

The selections of the appropriate type equipment or machines for construction often affect the required amount of time and effort and thus the job site productivity of a project. Equipment size determination is also a very important task for construction. Oversize equipments are expensive as well as consume more time to handle. It is therefore important for construction planners to be familiar with the characteristics of the major
types of equipment most commonly used in construction. Construction planners also have to know the sources of construction equipment.

Contractors and users of construction equipment frequently concerned with a decision as to whether to purchase or rent (lease) an equipment. Under certain conditions it is financially advantageous to purchase, whereas under other conditions it is more economical and satisfactory to rent it.

2.4.8 Building Materials

In recent times some of the important technological breakthroughs in materials are, stabilized soil, lime-pozzolana mixes, sand-lime bricks, fly-ash bricks, clay-fly ash bricks, gypsum boards, wood-wool sheets, plastic products in utility service, ready mix concrete, non-shrink grout for machine foundation, super-plasticizers, Ferro-cement and other materials. Different types of composite construction are also in very advance stage.

In the field of concrete technology also some advances are happened such as light weight concrete, radiation shielding concrete, polymer concretes, fiber reinforced concretes, super plasticized concretes, gap graded concrete, tenser-polymer reinforced concrete, roller-compacted concrete, ultra high strength concrete, improved techniques in pre-stressing, prefabricated construction and other some remarkable materials.

In low cost housing, a number of developments have taken place and following new techniques are being adopted for reduction in cost. These are stone block masonry, pre-cast brick panel roofing, pre-cast RC channel roofing, ferro-cement tank, use of secondary species of timber, particle board for shutter, doors/windows, fly ash-lime-gypsum bricks for making walls, pre-cast RCC frames for doors and windows, Pre-cast RC lintel (thin), lower ceiling heights, PVC pipes for water supply, stabilized soil cement base floors, magnesium oxy-chloride flooring, fire retardant treatment of thatch, asphalitic roofing, etc. Brief descriptions of some of those materials are below.
2.4.9 Construction Automation and Robotics

Recent advances in robotic technology and the related experience in manufacturing industries suggests that greater automation maybe extremely beneficial for constructed facilities. In addition, construction in hazardous environments (not approachable) may be greatly expanded by the use of construction robots.

There are several means by which construction automation and robotics might repay the additional equipment and development costs associated with high technology investments. First, robotics offers opportunities for extending the scope of practical construction activities into hazardous environments, including outer space, nuclear reactors, or undersea construction. Even standard construction sites represent hazardous environments as suggested by the large number job industrial accidents associated with construction. Second, robotics may permit the practical introduction and broader use of nonhuman senses and capabilities on construction sites.

Kajima Company’s reinforcing bar placing robot can carry up to 20 bars and automatically place these bars in pre-selected patterns in both floors and walls. The equipment has achieved 40% to 50% savings in labor and 10% savings in time on several Japanese projects.\textsuperscript{13}

A wall climbing robot called RM3 for tasks such as video inspections of ship hulls, gamma-ray inspection of structural welds, and high-pressure washing, painting, shot-blasting and barnacle removal.\textsuperscript{13}
3.1 Introduction

The contribution of construction industry is quite significant in the national economy but its existence is absent from the national economy plan. Recently government has made policy considering this sector as an industry. GDP Contribution of construction industry was 6.06 in 1991-1992 and 6.19 over the period 1996-1997. Agriculture sector contributes maximum of GDP. Construction sector contribute about 20% of agriculture sector GDP, which is a remarkable role in Bangladesh economy.\[16\]

The construction industry of Bangladesh comprises of a large number of predominantly small firms. The same can be seen to be true for most other countries.

The actual structure of the industry is not possible to measure as there are no published papers on the total number of firms. There are some 25,000 nos. of local contracting large, medium and small categorized firms registered with the government agencies with a varying range of financial capacities. [16]

In building construction sectors, larger firms are capable to construct concrete high-rise building. 30 storied Bangladesh Bank Bhaban, 20 storied Bangladesh Secretariat, 20 storied Sena Kalyan Bhaban Building, 20 storied IDB Bhaban and many other buildings are the evidence of the ability to construction of high rise concrete-building. While high rise steel structures are not yet familiar in Bangladesh but recently a number of high rise steel structure are under construction. In other sector such as bridge, roads, gas pipeline, electricity supply, dam, sluice-gate, etc are implemented by international contractors and joint venture companies (foreign and local firms). In 1990-91 the construction industry employed 1.05% and in 1995-96 1.83% (statistics '97) of total labour force. In other statistics showed that the constructing firm employs 20 lacs peoples. If each family comprise
of four members, so total 80 lacs people (6.15% of total population of the country) are dependent on the construction industry for their living. The economical and political significance of the industry is even greater than this figure suggest, as it captures the major part of the national investment. About 46% of the total construction labour force are involved in building, 50% in construction, repair and maintenance of roads and bridge works, and 4% are involved in construction repair and maintenance of other activities. [16]

Some domestic contractors in the building sectors have access to overseas market but local contractors are less capable of competing with the foreign companies, due to variety of grounds -

(a) Very Less initiative from the Government to improve the capacity of the local contractors

- Easy policy for credit system for construction industry
- To provide plant/ machinery hire facilities
- Skill and manpower development through training

(b) Policy of the rules and conditions of the donor agencies for foreign funds

According to PWD, to solve the housing problem 709,131 units of houses are required to construct in every year [15]. So it indicates that Bangladesh has a serious housing problem.

12 to 15 millions people now lives in Dhaka city. Dhaka, the capital of Bangladesh is now the city of construction. Though yearly requirements in the city is about 65,000 housing but all public and private sector together produce 25,000 housing units in a year. Percentage of leaving in slums and squatter settlement is about 30 percent. It would take at least 600 billion taka, which is five times the entire ADP budget of the country to accommodate house for the above-mentioned population. Very little areas are found in cities which are not occupied by building. Every place in the city is already filled up or construction of building process is ongoing. But the utility service and other facilities for community are not well thought-out. But according to government rules facilities shall be accommodate first
before any type of building construction. Unfortunately community facilities,
including simple parking facilities are still absent for the many new
constructing building in Dhaka city.

3.2 Some Large Constructions in Bangladesh

It is very difficult to identify, which one is large construction of a country
because of project diversity. In Bangladesh there are numerous
constructions, many of them are significant in various aspects. Although
functions and aesthetic are different of them, they accomplish different type
of requirements. Following are the some prominent constructions which
indicate Bangladesh building construction industry is fully capable to
construct any type of Building.

Equipments used for construction of national assembly building were tower
crane, larger size mixture machines and other equipment. Tower crane &
other equipments replaced by huge no of labors. As per definition of labour
based technology, construction of this building falls under this category.

National Assembly

![National Assembly](image)

Fig. 3-1 National Assembly

Labour Based Technology

Architect Louis I. Kahn

Location Dhaka, Bangladesh

Date 1962 to 1974

Building type government center

Construction System concrete, marble
Equipments used for construction of Bangladesh bank bhaban were hoist, mixture machine and other light equipment only. For excavation of 1-basement engaged huge no of labors. As per definition this type of construction falls under labour intensive technology.

1. **Bangladesh Bank Bhaban**

   ![Bangladesh Bank Bhaban](image)

   **Fig. 3-2 Bangladesh Bank Bhaban**

   **Labour Intensive Technology**

   Location Dhaka, Bangladesh

   No of Floors - 31

   Building type government

   Construction System concrete
Equipments used for construction of Islamic Development Bank Bhaban were tower crane, concrete pump, ready-mix concrete and other equipments. Tower crane, ready-mix concrete, concrete pump & other equipments replaced by most of the labors. As per definition of equipment intensive technology, this type of construction falls under this category.

- Islamic Development Bank

Location Dhaka, Bangladesh

No of Floors - 20

Construction System concrete

Fig. 3-3 Islamic Development Bank Bhaban

Equipment Intensive Technology
Equipments used for construction of Bashundhara city were tower crane, concrete pump, ready-mix concrete and other equipments. Tower crane, ready-mix concrete, concrete pump & other equipments replaced by most of the labors. As per definition of equipment intensive technology, this type of construction falls under this category.

**Bashundhara City**

![Fig. 3-4 Bashundhara City](image)

Architect VISTARA

Location Dhaka, Bangladesh

Date 1999 to 2003

Building type shopping mall

Construction System concrete, marble

3.3 Constructions in Bangladesh Using Pre Fabrication

Prefabricate construction not yet accepted widely in Bangladesh. Scenario of developed country in this respect is totally different. Even in Malaysia, Thailand, Indonesia, India and many other developing countries scenery is closed to developed countries. Prefabricate construction require customize construction or a huge no of similar type productions. Precast units which normally used in Bangladesh are -

- Tiles and mosaic
- Low cost toilet rings and others precast accessories.
- Prestressed precast electric pole
- Precast column for boundary wall
- Precast slab for surface drain
- Precast slab for foot path.
- Precast railing and ornamental column
- Precast lintel
- Precast pipe for water supply and others
- Railway sleeper
- Road divider

In the context of Bangladesh R&D activities are yet to be worthy. In Bangladesh "House and Building Research Institute" was established in the year 1977 with the following objectives –

1. To take technical and scientific studies and research on various problems of constructions and building materials, and to evolve housing and building technology appropriate to the requirement and suitable for socio-economic condition of the country.

2. To specifically emphasis on the study on availability, development and utilization of indigenous materials in construction.

3. To promote better uses of building materials particularly commonly used materials improvements methods of learning and designing of construction works and maintenance.

4. To train research personnel's and technicians for the purpose out its research activities.

House and Building Research Institute, time to time tried to introduce some precast module. Such as –

- Ferro cement tank
- Precast Ferro cement channel for roof and floor.
- Prestressed concrete hollow slab for roof and floor.
- Prestressed concrete micro pile
• Precast Ferro-cement folded plate for roof
• Precast Ferro-cement L panel for inclined roofing.
• RCC door and window frames

Between all type of innovation only Ferro cement tank (400 gallon consisting of cement mortar on wire mesh) is widely used mainly in Dhaka city. As bigger size is not possible with Ferro-cement, its use is limited.

Above all precast construction scenario is very poor in Bangladesh. This indicates construction technology not yet advance in Bangladesh in this high tech era.

3.4 Humnware, Infoware and Hardware in Bangladesh

3.4.1 Humnware

For construction technology humanware includes labour, technicians, engineer, and other persons. In some way they are related to construction industry. In Bangladesh expense for humanware is cheaper with respect to other countries, because of low wages. (In Bangladesh Taka 12.5 per hour and for ordinary labour, in UK £6). So utilization of man power through IT is a great opportunity for construction sector of Bangladesh. But unfortunately we are far way from proper utilization of this huge no manpower.

Development of Human resources is in very preliminary stage. By generating employment and working environment, general employment conditions need to be improved. Wage systems must be developed and made transparent so as to give proper remuneration according to qualification and technical skill. It is extremely necessary for the skilled workers to pass their skills on and to train personnel able to respond to future technological changes. Professional training centers and methods must be developed and be efficiently exercised upon.

In Bangladesh most of the cases we make out unskilled humanware which is unexpected in this high tech era. Also in most of the cases they are uneducated. Due to unskilled and uneducated labour, construction qualities
are not normally as per requirement. Also due to unskilled labor, excessive
time is requiring in most of the cases.

In Bangladesh labours are mainly trained-up by on-job training. In many case
they are habituated from paternal side by born. Though some training
institutes exist around Dhaka city but they are certificate-based institute.
These institutes deal only overseas job findings peoples.

3.4.2 Infoware

Infoware is usually the document-embodied form. This includes the
software, design specification, materials specifications, theories, charts,
database, drawing, design and others activities. Use of software in
Bangladesh for the purpose of analysis and design are in satisfactory level.

Although most of the organizations are now analyze and design by some
standard software but a big amount of engineers are not still away from this
technology. Following software and tools are now using in Bangladesh
which indicates not behind from top level.

Programming Language
- Visual Basic, Auto LISP, QBasic, C, C++, Turbo C

Computer Aided Engineering
- STAAD-II, STAAD/Pro, Math CAD, ADOSS, PCACOL, SDL Series

Spread Sheet Analysis
- Microsoft Excel, Lotus, MathCAD

Computer Aided Design
- AutoCAD

Database
- DBase, FoxPro, Microsoft Access, Oracle

GIS Software
- Arc/info, Arcade, MapInfo, Arc view, Idrisi,
Graphics software
- CorelDraw, Harvard Graphics

Computer Aided Project Management
- MS Project

Word Processing
- Microsoft Word, WordPerfect

Operating Systems
- MS Windows, Dos, Novel

3.4.3 Orgaware

Orgaware (Organization) represents the structural framework of a technological system and it includes, for example, the organizations for the R&D, the production the marketing, the corporate planning etc. It is needed to produce certain goods and services. Within the framework of the orgaware, the other technology components work. [1]

Most of the organization in Bangladesh is now using computer and software for different type of works. Some organizations are using for analysis and design, some for planning purpose, some as a management tools, and some one for data processing and accounting. In someway organizations of Bangladesh are taking this technological advantage.

In Bangladesh some organizations are doing a number of remarkable works excellently. They are creating photo realistic rendered architectural perspective models of 3D exterior and interior, elevation and layout rendering services, 3D animation. They are also creating architectural fly-by and walk-through simulations for interactive presentation or TV quality advertisement. GIS works are also done by these organizations.

Some of organizations are also working with foreign organizations. Mainly different type of data entry is their main works which are mainly data conversion from one format to another. Such as conversion from portable document format (pdf) to Word processing format (doc), hand sketch...
conversion to digital drawing (dwg, etc.) format, some modification of drawing etc. The difficulties of our organizations are, for any types of business they require an overseas office. This is a very big problem for entrepreneurs of data exchanging business.

3.4.4 Hardware

In Bangladesh hardware use of construction industry is not in a suitable level. Moreover specifically modern construction equipment / technology are not utilizing in Bangladesh most of the cases. Only in a few sector such as deeper excavation, in highway construction, a few no of building works are done by modern equipments but in other sectors, modern equipment are ignoring by Bangladeshi construction industry. Computer based hardware widely using in Bangladesh as computer and some computer related hardware are reasonably priced for middle class people.

For construction projects require modern management which is based on personal computer (PC). In Bangladesh computer based project management is not yet popular in construction industry. Only some foreign aided government project has some activities on this, but, also up-to proposal level only. Truly computer based project management in construction sector not yet implemented in Bangladesh. This is limited to some Gantt chart and critical path draw works. But hardware based computer management easily save both money and time. Probable cause for which not yet go for computer based project management listing below –

- Labours and technicians are illiterate
- Labours and technicians are unskilled
- Top management of an organization are not wanted to go for new particularly computer based technology.
- From Government side there are no plan to facilitate these sector even in Government project
- Our engineers backgrounds are also not upto that extent and also they are not interested to go for such type of management.
Nowaday's building construction mainly equipment intensive works all over the world, that is depend on modern technology. Similarly construction industry of Bangladesh going away step by step depends on technology. Technological application, sophistication, quality, etc are different in country to country but at every steps of construction industry; including construction industry of Bangladesh totally depends on construction technology. For excavation, loading, compaction, grading, drilling, lifting, erecting, mixing and other purposes require some construction hardware/equipment and there technological approach is different. Not only for equipment, but, in every steps of construction process depends on technological involvement. In this chapter mainly discussed the effect on excavation due to equipment intensive and labour intensive works. Also for building construction, the effect of alternate combination of material use.

4.1 Technology in Excavation

The substructure, or foundation, is that part of a structure which is usually placed below the surface of the ground. This foundation is mandatory for every structure. This is the reason of start of excavation technology, which is an earliest form of civil engineering construction. This technology is used for excavate earth of foundation/basement. Excavated soil/rock usually dumps in other places, which is known as loading. Many construction industry of Bangladesh, Excavator and Loader are mainly using for excavation works. But use of excavator is mostly Dhaka based. In other places of the country except Dhaka city, excavation works are done by manually, which is very unlikable in this high tech era. Even in Dhaka city, many excavation works had been done by manually. Such as 18 storied New Market City Complex building with two basements (adjacent of Dhaka new market), 14 storied CRP building project with two basements at Mirpur-
A few but in some projects, huge volume of soil was excavated manually. Excavation operations of these many projects are done by manually because of availability and low-priced labor. In this chapter try to focus why this technology (excavator) not used in most of the cases.

In many project of Bangladesh excavation operation are done by manually because of-

- **Soil Characteristics** - Comparatively soft layer of earth exists all around Bangladesh.
- **Labour (Hurnnware)** - Labour costs are cheap and available.
- **Non-availability of equipment (Hardware)** - Modern equipment cost is very high, for which, it is not possible for contractor to buy excavator and other heavy equipments for a single project.
- **No and size of the Job** - As no of projects limited and also areas of a single projects are not big. Use of Excavator and Loader are not economically viable.
- **Rental organization** - Rental organization not yet developed widely and systematically. Above all limited rental organization and their higher charges of hardware.
- **Topography** - Most of the lands in Bangladesh are plain. So labors can work comfortably.
- **Lacks of technicians** - Lack of skilled technicians are one of the reasons to avoid new technology.
- **Time** - Peoples of Bangladesh are not anxious about time. Utilization of time is very important; lack of this awareness is one of the reasons of avoiding tendency of new technology for excavation.
- **Space constrains** - Particularly in Dhaka city, buildings are not build in well planned way but very haphazard. So in many case movement of excavator is very difficult and in some cases it is impossible to work due to space constrain.
Weather and Temperature – Luckily most of the seasons are suitable for labour works. Nature is very fever for manual labour, except, very little time through out the year. So not need to take extra precaution for climate.

Dumping area – Some time huge amount of dumping is not possible. For that reason avoiding tendency to new technology of excavation.

Transportation equipments – Some times transportation of dumping is not viable and in that type of case manual labour is preferable.

4.1.1 Preliminary Stage

The substructure, or foundation, is that part of a structure, which is usually placed below the surface of the ground, and which transmits the load to the underlying soil or rock. As the foundation normally placed below the ground, excavation is must and should be done first for any type of construction work.

More or less for every construction works need excavation, some times these are shallow and some times it is deep. Due to basement construction of high-rise buildings need massive excavation. This may need up to three four months. If excavation works are done by manually, a huge no of labors will engage their and require more time.

Considering employment, it is solving a substantial social problem like our developing country by means of giving a large no of employment opportunity. Therefore out side the urban area manual excavation may be permissible due to solving unemployment problem. This might be playing a significant role like our developing country to solve the problem. Social problem from society. But owners always try to solve the problem from the economic view, which, will figure out later on this chapter.

But the scenario in urban areas like Dhaka city is different. Dhaka has already become a mega city with more than ten million inhabitants, and its population is projected to reach 16 million by 2015, which would make it the world’s seventh most populous city. This rapid growth is visible all
around the city by constructing new buildings. But the city’s infrastructure is not keeping pace with the influx of population. Transport environment of Dhaka city may be a clear example, with increasing traffic congestion and delays. The ability of Dhaka’s transport system to sustain economic growth and reasonable quality of life has been declining steadily.

In such a poor situation, if we don’t use machinery equipment, everyday congestion situation of Dhaka city will escalate, due to longer time requirement of excavation.

Already it is an established fact that construction works of Dhaka city is one of main reasons of traffic congestion. To overcome this awful situation, particularly in the city areas we must have to adopt modern technology in excavation purpose. This will help to reduce construction time, money, traffic congestion and other redundant situations.

4.1.2 Time and Seasonal Effects on Construction

Time

In Bangladesh construction management going on very preliminary stage and still they don’t think time is a vital factor for any project. But everyone is aware the fact “money has a time value”. Thousand Taka today is worth more the Thousand tomorrow. This fact is vividly reinforced when the monthly charge bills are examined. This added charge amounts to rent on the money that is owed, and is termed interest.

Besides these we know fixed costs are directly related to time, variable and other costs are also similar effect, i.e. if time span of a project is longer then fixed cost will be more and similarly true for all other costs. So time span is a vital factor for any construction project.

Again for any project there is a breakeven point, which also dependents on time. If construction period is more than the estimated time, time requirement to reach break even will be more.

Besides these there is a possibility to come other competitors due to delay of construction and sometimes it may become an unprofitable project for ever in this competitive market.
If we consider revenue side what we see - Suppose a 10 storied office building spaces are 12000 sq-ft and rent is 50/= Taka per sq-ft. i.e. per day revenue is 2.0 Lac. Particularly this type of project per day revenue loss will be a big amount, if, the construction not timely finish. This is unexpected for any organization(s)/contractor(s).

Season

In many cases for foundation purpose, deep excavation is required. Sometimes need shore pile to protect adjacent soil. Shore pile is essential when permanent structure exist adjacent project site. As shore pile is a temporary work, in many cases it designs less cautiously. Result is that shore pile failures are a common type of failure in Dhaka city at every year. It is occurred mainly in rainy season due to rainfall. If the contractors are finished their foundation works before rainy season, most of the time they can avoid these repetitive shore pile failure situations.

On the other hand, in many cases owner of adjacent structure goes to the court when contractor goes for deeper excavation for their safety and compensation if shore pile failure occurs. Also for shore pile failure delays the project i.e. more time consume for project and more money expenses due to delay or to pay compensation. Sometimes it becomes a crucial factor for the project and as a result of big economical loss for that project. Such type of big economical loss easily can avoid by proper time scheduling, i.e. should be complete before expected rainy season in case of deeper foundation works.
4.1.3 Cost Analysis and Result

Assumption made for cost and analysis are follows-

1. For Manual 1000 cft of excavation work (PWD Standard Rates)
   a) For initial lead of 100'-0" and lift of 5'-0"
      i) Ordinary labour cost Tk. 0.88 per cft
   b) For each additional lift of one foot beyond 5'-0" and upto 10'-0"
      i) Extra ordinary labour cost Tk. 0.04 per cft
   c) For each additional lift of one foot beyond 10'-0" and upto 15'-0"
      i) Extra ordinary labour cost Tk. 0.06 per cft
   d) For each additional lift of one foot beyond 15'-0" and upto 20'-0"
      i) Extra ordinary labour cost Tk. 0.08 per cft
   e) Extra each additional lead of 100'-0"
      i) Extra ordinary labour cost Tk. 0.14 per cft

2. For Excavator
   f) Initial rent Tk. 90,000.00 for upto 10 days
      i) Extra charge Tk. 10,000.00 per day
      ii) Excavation capacity 10000 cft per day

3. Enough Labour Force
   g) Enough labour force can be engaged so that there will not be any significant difference in excavation between these two methods.
### Table 4-1: 5' EXCAVATION COST (MANUAL VS EXCAVATOR)

<table>
<thead>
<tr>
<th>Area (ft²)</th>
<th>Volume (ft³)</th>
<th>Manual (Cost, Tk.)</th>
<th>Excavator (Cost, Tk.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
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<td>440</td>
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<td>218,000</td>
<td>180000</td>
</tr>
<tr>
<td>100000</td>
<td>500000</td>
<td>755,000</td>
<td>450000</td>
</tr>
</tbody>
</table>

### Table 4-2: 10' EXCAVATION COST (MANUAL VS EXCAVATOR)

<table>
<thead>
<tr>
<th>Area (ft²)</th>
<th>Volume (ft³)</th>
<th>Manual (Cost, Tk.)</th>
<th>Excavator (Cost, Tk.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1000</td>
<td>580</td>
<td>90000</td>
</tr>
<tr>
<td>200</td>
<td>2000</td>
<td>1,960</td>
<td>90000</td>
</tr>
<tr>
<td>500</td>
<td>5000</td>
<td>4,900</td>
<td>90000</td>
</tr>
<tr>
<td>1000</td>
<td>10000</td>
<td>9,800</td>
<td>90000</td>
</tr>
<tr>
<td>2000</td>
<td>20000</td>
<td>19,600</td>
<td>90000</td>
</tr>
<tr>
<td>5000</td>
<td>50000</td>
<td>49,000</td>
<td>90000</td>
</tr>
<tr>
<td>10000</td>
<td>100000</td>
<td>98,000</td>
<td>90000</td>
</tr>
<tr>
<td>20000</td>
<td>200000</td>
<td>210,000</td>
<td>180000</td>
</tr>
<tr>
<td>40000</td>
<td>400000</td>
<td>476,000</td>
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</tr>
<tr>
<td>100000</td>
<td>1000000</td>
<td>1,610,000</td>
<td>900000</td>
</tr>
</tbody>
</table>

41
### Table 4-3: 15' EXCAVATION COST (MANUAL VS EXCAVATOR)

<table>
<thead>
<tr>
<th>Area (ft²)</th>
<th>Volume (ft³)</th>
<th>Manual (Cost, Tk.)</th>
<th>Excavator (Cost, Tk.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1500</td>
<td>1,670</td>
<td>90000</td>
</tr>
<tr>
<td>200</td>
<td>3000</td>
<td>3,340</td>
<td>90000</td>
</tr>
<tr>
<td>500</td>
<td>7500</td>
<td>8,350</td>
<td>90000</td>
</tr>
<tr>
<td>1000</td>
<td>15000</td>
<td>16,700</td>
<td>90000</td>
</tr>
<tr>
<td>2000</td>
<td>30000</td>
<td>33,400</td>
<td>90000</td>
</tr>
<tr>
<td>5000</td>
<td>75000</td>
<td>83,500</td>
<td>90000</td>
</tr>
<tr>
<td>10000</td>
<td>150000</td>
<td>167,000</td>
<td>135000</td>
</tr>
<tr>
<td>20000</td>
<td>300000</td>
<td>355,000</td>
<td>270000</td>
</tr>
<tr>
<td>50000</td>
<td>750000</td>
<td>794,000</td>
<td>540000</td>
</tr>
<tr>
<td>100000</td>
<td>1500000</td>
<td>2,615,000</td>
<td>1350000</td>
</tr>
</tbody>
</table>

### Table 4-4: 20' EXCAVATION COST (MANUAL VS EXCAVATOR)

<table>
<thead>
<tr>
<th>Area (ft²)</th>
<th>Volume (ft³)</th>
<th>Manual (Cost, Tk.)</th>
<th>Excavator (Cost, Tk.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>2000</td>
<td>2,560</td>
<td>90000</td>
</tr>
<tr>
<td>200</td>
<td>4000</td>
<td>5,120</td>
<td>90000</td>
</tr>
<tr>
<td>500</td>
<td>10000</td>
<td>12,800</td>
<td>90000</td>
</tr>
<tr>
<td>1000</td>
<td>20000</td>
<td>25,000</td>
<td>90000</td>
</tr>
<tr>
<td>2000</td>
<td>40000</td>
<td>51,200</td>
<td>90000</td>
</tr>
<tr>
<td>5000</td>
<td>100000</td>
<td>128,000</td>
<td>90000</td>
</tr>
<tr>
<td>10000</td>
<td>200000</td>
<td>256,000</td>
<td>180000</td>
</tr>
<tr>
<td>20000</td>
<td>400000</td>
<td>540,000</td>
<td>360000</td>
</tr>
<tr>
<td>40000</td>
<td>800000</td>
<td>1,192,000</td>
<td>720000</td>
</tr>
<tr>
<td>100000</td>
<td>2000000</td>
<td>3,820,000</td>
<td>1800000</td>
</tr>
</tbody>
</table>
Graph 4-1: Excavation cost for 5 feet

Graph 4-2: Excavation cost for 10 feet
Graph 4-3: Excavation cost for 15 feet

Graph 4-4: Excavation cost for 20 feet
From the above analysis it is observed that in case of 5 feet excavation break-even area is 19020 sft, for 10 feet excavation 9184 sft, for 15 feet excavation 6946 sft and for 20 ft 3636 sft. Excavator becomes cheaper for any construction (area) above these break-even levels.

4.2 Design and Specifications

4.2.1 Material for Building Construction

Wood, of course, was the only material used by early builders that had more or less equal tensile and compressive strength. Early builders are also depends on stone, brick, surki, and lime. After innovation of reinforced-concrete and steel, previously used material, are replaced by concrete and steel. Concrete with reinforcement radically change in the field of building construction technology. After that steel play the vital role and contribute to build high rise building worldwide though Bangladesh is far from that type high rise building. But recently numbers of steel building are in the process of construction and we are expecting remarkable progress will be shown within couple of years. Now a day's wood has been relegated largely to accessory use during construction, to use in temporary and secondary structures, and to use for secondary member of permanent construction.

Though both concrete and steel are the two most commonly used structural material worldwide, in Bangladesh mainly concrete are common item of building construction. Recently some industrial buildings are constructed by structural steel. Builders in Bangladesh are now realizing that steel is also a competitive and effective material for building construction. But they are going forward very slowly for steel structure.

Selection of structural materials must be selected on availability of materials. Also depends on corresponding skill labour, relative costs, wage scale and the suitability of the materials for particular structure.

In Bangladesh currently carrying out research into rice straw and husks, which are a by-product of major crop of Bangladesh but have already encountered problems with the strength of the rice straw, while at best, rice
husks can be regarded as ‘filler’ and may not contribute significantly to the tensile strength of earth-mix bricks.

Idea of including waste material from the country’s vast jute industry to use as a binder in the bricks and not merely as rubbish to be burnt.

And finally, that the integrity of earth-built buildings may be considerably strengthened and improved by applying simple, low-cost principles to the internal strengthening structures - mostly tied bamboo frameworks.

4.2.1.1 Material in Bangladesh

Any material which has got application in engineering construction is termed as engineering material. Stones, bricks, concrete bricks, lime, cement, surki, sand, concrete, iron, steel, ferrous alloys, non-ferrous metals and alloys, timber, timber products, aluminum, bamboo, soils, bituminous materials, glass, plastics, paints, varnishes, rubber, tiles, granite, marble, etc are commonly used in Bangladesh.

Among them, major construction materials are now producing in Bangladesh though maximum raw materials are imported outside from Bangladesh.

Though cement raw materials like gypsum and clinker are importing from outside of country, the total cement producing capacity now, is more than country’s per year requirement and quality of cement is standard as per specification. But reinforcement quality is not yet reached to standard level. It is very serious problem for construction industry of Bangladesh.
4.2.1.2 Reinforcement

Steel is known as black copper in early ages. Iron and steel developed over 2000 years ago. It was Henry Bessemer who was especially interested in good quality steel making for big canons; He was the first to produce low carbon wrought iron. In Bangladesh steel also used as reinforcement in many years before. It is difficult to say when and where first time used steel reinforcement.

Concrete reinforcement bar are usually of two types

- Deformed bar and
- Twisted bar

Below are the specifications for two types of reinforcement bar-

<table>
<thead>
<tr>
<th>Steel Grade</th>
<th>Yield Strength (psi)</th>
<th>Ultimate Strengths (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 40</td>
<td>40,000 (minimum)</td>
<td>70,000 (minimum)</td>
</tr>
<tr>
<td>Grade 60</td>
<td>60,000 (minimum)</td>
<td>90,000 (minimum)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Steel Grade</th>
<th>Yield Strength (psi)</th>
<th>Ultimate Strengths (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 250</td>
<td>40,000 (minimum)</td>
<td>44,000</td>
</tr>
<tr>
<td>Grade 400</td>
<td>60,000 (minimum)</td>
<td>66,000</td>
</tr>
<tr>
<td>Grade 460</td>
<td>67,000 (minimum)</td>
<td>73,700</td>
</tr>
</tbody>
</table>

Grade 40 and Grade 60 both type of reinforcement are frequently used in Bangladesh for building construction. In Bangladesh normally steel are processed by the following method

1. Induction furnace melting and
2. Arc furnace melting.

The yearly requirement of steel in Bangladesh is 1.0 million ton. But the quality steel production rate is only 0.2 million ton/year. That is remaining 0.8 million ton reinforcement are non-standard. By which our different construction works are building. This is an awful situation of construction sector in Bangladesh and requires immediate exemption from this situation.
4.2.1.3 Concrete

All over the world concrete with reinforcement are the most commonly used materials for building construction. In Bangladesh it is the main structural material using as building construction materials. Concrete is a stone like material obtained by permitting a carefully proportioned mixture of cement, sand and gravel or other aggregate, and water to harden in forms of the shape and dimensions of the desired structure.

Bangladesh is now a big cement producing country in respect to their required capacity. Statistics says yearly requirement of cement all over the Bangladesh is 6.5 million tons where as production capacity of the entire cement mill is 12.0 million tons. That means 5.5 million tons surplus cement now existing in Bangladesh. One of the main reasons of this surplus is that, world top most cement producing companies are now producing cement in Bangladesh from their factory.

The properties that make concrete a universal building material are so pronounced that it has been used, in more primitive kinds and ways than at present for thousands of years, probably beginning in Egyptian antiquity. The facility with which, while plastic, it can be deposited and made to fill forms or, olds of almost any practical shape is one of these factors. Its high fire and weather resistance are evident advantages. Most of the constituent materials, with the possible exception of cement, are usually available at low cost locally or at small distances from the construction site.

In Bangladesh normally concrete strength (cylinder strength fc') varies from 2500 psi to 5000 psi for building construction. But in many case it falls to 2000 psi. On the other hand upto 8000 psi concrete was used for construction of Jamuna Multipurpose Bridge project. Also there are many projects already finished and ongoing, where used/using more than 5000 psi strength concrete.
4.2.1.4 Steel

In 1885, an American engineer names William LeBaron Jenny became the creator of the modern skyscraper when he realized that an office building could be constructed using totally different materials. He chose structural steel and incorporated it into a revolutionary system that was to make possible the soaring office towers that now symbolize the modern metropolis.

Steel is manufactured under controlled conditions; its properties are determined in a laboratory and described in a manufacturer's certificate. Thus the designer need only specify the steel as complying with a relevant standard, and the site engineer's supervision is limited to the workmanship of the connections between the individual steel members. So responsible of contractor is more to provide proper material.

Also following are some reasons normally associated with competitive advantages of steel over concrete:

- Construction speed, particularly during periods of high interest rates. Steel frames go up more rapidly, thus reducing construction financing costs and allowing the building to generate revenue sooner.

- Availability of steel in a variety of grades and shapes that is suitable for economical framing of both short and long spans.

- Steel offers economical design approach for retrofit and rehab projects. Steel can be easily modified, expanded, or converted to suit future needs of owners and tenants. For this reason steel frame is often referred to as a changeable frame.

- In difficult foundation conditions, steel construction may result in reduced foundation costs because of its light weight. Steel frame is normally 25 to 35 percent lighter than a concrete frame and can permit the use of less expensive foundation systems.

In Bangladesh steel building are not constructing notably. Mainly some factory buildings are constructed with steel as a structural material. In Bangladesh peoples are not serious about time which is main advantage of steel structure like our country. We have to import all the steel materials. It
also has to pay higher tax. Our engineers are not interested to go for new technology like steel structure. Our technicians and labors are not yet trained up for steel construction. Ultimately except time factor, steel structure is not very suitable for building construction of Bangladesh. Very recently a few numbers of high-rise buildings are now under construction or under designing stages which indicates new technology are coming.

4.2.1.5 R.C.C. Grading

Strength of concrete is commonly considered its most important property, although in many practical cases other characteristic such as durability and impermeability may in fact be more important. Nevertheless, strength usually gives an overall picture of the quality of concrete because strength is directly related to the structure of the hardened cement paste.

The strength of concrete of given mix proportions is very seriously affected by the degree of its compaction; it is vital, therefore, that consistence of the mix be such that the concrete can be transported, placed and finished sufficiently easily and without segregation. Following combinations of reinforcement and concrete are considered for this study:

Table 4-7: Different Combinations of Reinforcement and Concrete

<table>
<thead>
<tr>
<th>Concrete Type</th>
<th>Steel Strength (in ksi)</th>
<th>Concrete Strength (in ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type - 1</td>
<td>60</td>
<td>4.4</td>
</tr>
<tr>
<td>Type - 2</td>
<td>60</td>
<td>3.6</td>
</tr>
<tr>
<td>Type - 3</td>
<td>60</td>
<td>2.9</td>
</tr>
<tr>
<td>Type - 4</td>
<td>60</td>
<td>2.5</td>
</tr>
<tr>
<td>Type - 5</td>
<td>40</td>
<td>4.4</td>
</tr>
<tr>
<td>Type - 6</td>
<td>40</td>
<td>3.6</td>
</tr>
<tr>
<td>Type - 7</td>
<td>40</td>
<td>2.9</td>
</tr>
<tr>
<td>Type - 8</td>
<td>40</td>
<td>2.5</td>
</tr>
</tbody>
</table>
4.2.1.7 Interdependence of Humnware, Infoware and Hardware

For analysis and design purpose humnware, infoware and hardware work as an integrated system. During design and analysis period, due to different grade and type material selection, software, hardware and humnware play the vital role for alternate attempt. Computer utilization in different stages have improved capabilities for generating quality designs as well as reducing the time required to produce alternative designs. Without help of these technological combined services, it is almost impossible, to get, better and optimistic design. That's why with the help of Humnware, Infoware and Hardware most economic type analysis and design may achieved within short time, which is almost impossible without these technological help.

Manual analysis and design are most of the time assumption based, a time consuming matter and whose ultimate result is economical loss considered to both time and material requirement.
4.2.1.8 Analysis and Result

For analysis purpose here considered a six storied building. The analysis has been performed by STAAD/Pro software. 3-D model of assumed building & output of STAAD/Pro are given in Appendix A.

Following are the material requirement for different combination.

Table 4-8: Material Requirement for Column
(Concrete Strength 4.4 ksi and Reinf. Strength 60 ksi)

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>10487 lbs</td>
</tr>
<tr>
<td>5</td>
<td>2148 lbs</td>
</tr>
<tr>
<td>6</td>
<td>1375 lbs</td>
</tr>
<tr>
<td>7</td>
<td>1396 lbs</td>
</tr>
<tr>
<td>8</td>
<td>3971 lbs</td>
</tr>
</tbody>
</table>

Total weight of reinforcement = 19365 lbs
Total Volume of Concrete = 2868.8 cu.ft

Table 4-9: Material Requirement for Beam
(Concrete Strength 4.4 ksi and Reinf. Strength 60 ksi)

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>23844 lbs</td>
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<tr>
<td>5</td>
<td>1346 lbs</td>
</tr>
<tr>
<td>6</td>
<td>5329 lbs</td>
</tr>
<tr>
<td>7</td>
<td>5487 lbs</td>
</tr>
<tr>
<td>8</td>
<td>10511 lbs</td>
</tr>
</tbody>
</table>

Total weight of reinforcement = 46518 lbs
Total Volume of Concrete = 6145.4 cu.ft
Table 4-10: Material Requirement for Column  
(Concrete Strength 3.6 ksi and Reinf. Strength 60 ksi)

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>(in lbs)</td>
</tr>
<tr>
<td>4</td>
<td>6330 lbs</td>
</tr>
<tr>
<td>5</td>
<td>5653 lbs</td>
</tr>
<tr>
<td>6</td>
<td>1644 lbs</td>
</tr>
<tr>
<td>7</td>
<td>2771 lbs</td>
</tr>
<tr>
<td>8</td>
<td>4722 lbs</td>
</tr>
</tbody>
</table>

Total weight of reinforcement = 21120 lbs  
Total Volume of Concrete = 3355 cu.ft

Table 4-11: Material Requirement for Beam  
(Concrete Strength 3.6 ksi and Reinf. Strength 60 ksi)

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>(in lbs)</td>
</tr>
<tr>
<td>4</td>
<td>22348 lbs</td>
</tr>
<tr>
<td>5</td>
<td>4039 lbs</td>
</tr>
<tr>
<td>6</td>
<td>8655 lbs</td>
</tr>
<tr>
<td>7</td>
<td>4001 lbs</td>
</tr>
<tr>
<td>8</td>
<td>5049 lbs</td>
</tr>
</tbody>
</table>

Total weight of reinforcement = 44092 lbs  
Total Volume of Concrete = 7279 cu.ft
<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight (in lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>7871.9 lbs</td>
</tr>
<tr>
<td>5</td>
<td>2989.8 lbs</td>
</tr>
<tr>
<td>6</td>
<td>3750.5 lbs</td>
</tr>
<tr>
<td>7</td>
<td>5725.7 lbs</td>
</tr>
<tr>
<td>8</td>
<td>5875.4 lbs</td>
</tr>
</tbody>
</table>

**Total weight of reinforcement** = 26213 lbs

**Total Volume of Concrete** = 3528 cu.ft

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight (in lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>22182 lbs</td>
</tr>
<tr>
<td>5</td>
<td>10011 lbs</td>
</tr>
<tr>
<td>6</td>
<td>3755.2 lbs</td>
</tr>
<tr>
<td>7</td>
<td>6918 lbs</td>
</tr>
<tr>
<td>8</td>
<td>342.97 lbs</td>
</tr>
</tbody>
</table>

**Total weight of reinforcement** = 43219 lbs

**Total Volume of Concrete** = 9367 cu.ft
Table 4-14: Material Requirement for Column
(Concrete Strength 2.5 ksi and Reinforce. Strength 60 ksi)

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight (in lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>9556 lbs</td>
</tr>
<tr>
<td>5</td>
<td>2453 lbs</td>
</tr>
<tr>
<td>6</td>
<td>3610 lbs</td>
</tr>
<tr>
<td>7</td>
<td>6378 lbs</td>
</tr>
<tr>
<td>8</td>
<td>6761 lbs</td>
</tr>
</tbody>
</table>

Total weight of reinforcement = 28958 lbs
Total Volume of Concrete = 4190 cu.ft

Table 4-15: Material Requirement for Beam
(Concrete Strength 2.5 ksi and Reinforce. Strength 60 ksi)

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight (in lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>25557 lbs</td>
</tr>
<tr>
<td>5</td>
<td>3126 lbs</td>
</tr>
<tr>
<td>6</td>
<td>4340 lbs</td>
</tr>
<tr>
<td>7</td>
<td>10008 lbs</td>
</tr>
<tr>
<td>8</td>
<td>703 lbs</td>
</tr>
</tbody>
</table>

Total weight of reinforcement = 43733 lbs
Total Volume of Concrete = 10076 cu.ft
Table 4-16: Material Requirement for Column
(Concrete Strength 4.4 ksi and Reinf. Strength 40 ksi)

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight (in lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>8680 lbs</td>
</tr>
<tr>
<td>5</td>
<td>1358 lbs</td>
</tr>
<tr>
<td>6</td>
<td>1434 lbs</td>
</tr>
<tr>
<td>7</td>
<td>2588 lbs</td>
</tr>
<tr>
<td>8</td>
<td>7727 lbs</td>
</tr>
</tbody>
</table>

Total weight of reinforcement = 21787 lbs
Total Volume of Concrete = 3499 cu.ft

Table 4-17: Material Requirement for Beam
(Concrete Strength 4.4 ksi and Reinf. Strength 40 ksi)

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight (in lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>17629 lbs</td>
</tr>
<tr>
<td>5</td>
<td>4878 lbs</td>
</tr>
<tr>
<td>6</td>
<td>7745 lbs</td>
</tr>
<tr>
<td>7</td>
<td>792.1 lbs</td>
</tr>
<tr>
<td>8</td>
<td>16895 lbs</td>
</tr>
</tbody>
</table>

Total weight of reinforcement = 47938 lbs
Total Volume of Concrete = 8546 cu.ft
### Table 4-18: Material Requirement for Column
(Concrete Strength 3.6 ksi and Reinf. Strength 40 ksi)

<table>
<thead>
<tr>
<th>Bar Size Number</th>
<th>Weight (in lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>7770 lbs</td>
</tr>
<tr>
<td>5</td>
<td>1432 lbs</td>
</tr>
<tr>
<td>6</td>
<td>3795 lbs</td>
</tr>
<tr>
<td>7</td>
<td>4686 lbs</td>
</tr>
<tr>
<td>8</td>
<td>9068 lbs</td>
</tr>
</tbody>
</table>

Total weight of reinforcement = 26752 lbs

Total Volume of Concrete = 3479 cu.ft

### Table 4-19: Material Requirement for Beam
(Concrete Strength 3.6 ksi and Reinf. Strength 40 ksi)

<table>
<thead>
<tr>
<th>Bar Size Number</th>
<th>Weight (in lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>17705 lbs</td>
</tr>
<tr>
<td>5</td>
<td>1591 lbs</td>
</tr>
<tr>
<td>6</td>
<td>13078 lbs</td>
</tr>
<tr>
<td>7</td>
<td>1152 lbs</td>
</tr>
<tr>
<td>8</td>
<td>16675 lbs</td>
</tr>
</tbody>
</table>

Total weight of reinforcement = 50201 lbs

Total Volume of Concrete = 9644 cu.ft
Table 4-20: Material Requirement for Column  
(Concrete Strength 2.9 ksi and Rein. Strength 40 ksi)

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>8476.4 lbs</td>
</tr>
<tr>
<td>5</td>
<td>3084.6 lbs</td>
</tr>
<tr>
<td>6</td>
<td>2226.4 lbs</td>
</tr>
<tr>
<td>7</td>
<td>3423.2 lbs</td>
</tr>
<tr>
<td>8</td>
<td>10168 lbs</td>
</tr>
</tbody>
</table>

Total weight of reinforcement = 27379 lbs
Total Volume of Concrete = 4709 cu.ft

Table 4-21: Material Requirement for Beam  
(Concrete Strength 2.9 ksi and Rein. Strength 40 ksi)

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>17693 lbs</td>
</tr>
<tr>
<td>5</td>
<td>2347 lbs</td>
</tr>
<tr>
<td>6</td>
<td>19086 lbs</td>
</tr>
<tr>
<td>7</td>
<td>1367 lbs</td>
</tr>
<tr>
<td>8</td>
<td>13352 lbs</td>
</tr>
</tbody>
</table>

Total weight of reinforcement = 53845 lbs
Total Volume of Concrete = 10111 cu.ft
### Table 4-22: Material Requirement for Column
(Concrete Strength 2.5 ksi and Reinf. Strength 40 ksi)

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight (in lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>6602 lbs</td>
</tr>
<tr>
<td>5</td>
<td>2506 lbs</td>
</tr>
<tr>
<td>6</td>
<td>7068 lbs</td>
</tr>
<tr>
<td>7</td>
<td>5216 lbs</td>
</tr>
<tr>
<td>8</td>
<td>8370 lbs</td>
</tr>
</tbody>
</table>

**Total weight of reinforcement = 29762 lbs**

**Total Volume of Concrete = 5055 cu.ft**

### Table 4-23: Material Requirement for Beam
(Concrete Strength 2.5 ksi and Reinf. Strength 40 ksi)

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight (in lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>18686 lbs</td>
</tr>
<tr>
<td>5</td>
<td>13536 lbs</td>
</tr>
<tr>
<td>6</td>
<td>15858 lbs</td>
</tr>
<tr>
<td>7</td>
<td>1085 lbs</td>
</tr>
<tr>
<td>8</td>
<td>5565 lbs</td>
</tr>
</tbody>
</table>

**Total weight of reinforcement = 54730 lbs**

**Total Volume of Concrete = 11269 cu.ft**
4.2.1.9 Cost Analysis

Generally the cost for a construction project includes the expenses related to the following activities:

- Land acquisition
- Planning and feasibility
- Design
- Construction, including materials, equipment and labour
- Insurance and taxes during construction
- Office overhead
- Office furniture and equipment
- Inspection, testing and others

In this study considered only material cost of different grade of combination which is mentioned in the article 4.2.1.5

Table 4-24: Concrete Cost as Per PWD Schedule

<table>
<thead>
<tr>
<th>Concrete Strength</th>
<th>Concrete Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2500 psi</td>
<td>155 Tk/cft</td>
</tr>
<tr>
<td>2900 psi</td>
<td>164 Tk/cft</td>
</tr>
<tr>
<td>3600 psi</td>
<td>187 Tk/cft</td>
</tr>
<tr>
<td>4400 psi</td>
<td>209 Tk/cft</td>
</tr>
</tbody>
</table>

Table 4-25: Reinforcement Cost as Per PWD Schedule

<table>
<thead>
<tr>
<th>Reinforcement Strength</th>
<th>Reinforcement Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>40000 psi</td>
<td>22640.6 Tk/ton</td>
</tr>
<tr>
<td>60000 psi</td>
<td>23625 Tk/ton</td>
</tr>
</tbody>
</table>
### Table 4-26: Reinforcement and Concrete Requirement

<table>
<thead>
<tr>
<th>Type of Concrete</th>
<th>Reinforcement Requirement</th>
<th>Concrete Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type - 1</td>
<td>29.4 Ton</td>
<td>9014 cft</td>
</tr>
<tr>
<td>Type - 2</td>
<td>29.1 Ton</td>
<td>10633 cft</td>
</tr>
<tr>
<td>Type - 3</td>
<td>31.0 Ton</td>
<td>12895 cft</td>
</tr>
<tr>
<td>Type - 4</td>
<td>32.5 Ton</td>
<td>14266 cft</td>
</tr>
<tr>
<td>Type - 5</td>
<td>31.1 Ton</td>
<td>12044 cft</td>
</tr>
<tr>
<td>Type - 6</td>
<td>34.4 Ton</td>
<td>13123 cft</td>
</tr>
<tr>
<td>Type - 7</td>
<td>36.3 Ton</td>
<td>14821 cft</td>
</tr>
<tr>
<td>Type - 8</td>
<td>37.7 Ton</td>
<td>18324 cft</td>
</tr>
</tbody>
</table>

### Table 4-27: Actual Reinforcement and Concrete Requirement

<table>
<thead>
<tr>
<th>Type of Concrete</th>
<th>Reinforcement Requirement</th>
<th>Concrete Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type - 1</td>
<td>44.1 Ton</td>
<td>9916 cft</td>
</tr>
<tr>
<td>Type - 2</td>
<td>43.7 Ton</td>
<td>11697 cft</td>
</tr>
<tr>
<td>Type - 3</td>
<td>46.5 Ton</td>
<td>14185 cft</td>
</tr>
<tr>
<td>Type - 4</td>
<td>48.7 Ton</td>
<td>15693 cft</td>
</tr>
<tr>
<td>Type - 5</td>
<td>46.7 Ton</td>
<td>13249 cft</td>
</tr>
<tr>
<td>Type - 6</td>
<td>51.5 Ton</td>
<td>14435 cft</td>
</tr>
<tr>
<td>Type - 7</td>
<td>54.4 Ton</td>
<td>16304 cft</td>
</tr>
<tr>
<td>Type - 8</td>
<td>56.6 Ton</td>
<td>17857 cft</td>
</tr>
</tbody>
</table>

### Table 4-28: Reinforcement and Concrete Cost in 1,00,000 Taka

<table>
<thead>
<tr>
<th>Type of Concrete</th>
<th>Reinforcement Cost</th>
<th>Concrete Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type - 1</td>
<td>10.42 Lac</td>
<td>18.84 Lac</td>
<td>29.26 Lac</td>
</tr>
<tr>
<td>Type - 2</td>
<td>10.32 Lac</td>
<td>19.88 Lac</td>
<td>30.20 Lac</td>
</tr>
<tr>
<td>Type - 3</td>
<td>10.99 Lac</td>
<td>21.15 Lac</td>
<td>32.14 Lac</td>
</tr>
<tr>
<td>Type - 4</td>
<td>11.50 Lac</td>
<td>22.11 Lac</td>
<td>33.61 Lac</td>
</tr>
<tr>
<td>Type - 5</td>
<td>10.87 Lac</td>
<td>25.17 Lac</td>
<td>36.04 Lac</td>
</tr>
<tr>
<td>Type - 6</td>
<td>11.67 Lac</td>
<td>24.54 Lac</td>
<td>36.21 Lac</td>
</tr>
<tr>
<td>Type - 7</td>
<td>12.31 Lac</td>
<td>24.31 Lac</td>
<td>36.62 Lac</td>
</tr>
<tr>
<td>Type - 8</td>
<td>12.81 Lac</td>
<td>25.30 Lac</td>
<td>38.11 Lac</td>
</tr>
</tbody>
</table>
Above analysis clearly shows that Type-1 concrete is cheaper than any other combination of reinforced concrete. Up-to 29% savings is possible if higher grade Reinforcement and Concrete used for building construction.
CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

In developed countries civil engineering organizations spend good amount of money in R&D. At national level, the universities and other institutions should be encouraged to undertake strategic research which aims to improve understanding and applications of scientific and technical know how which in turn will provide a basis in the long run proper application of new techniques and technologies. Following are some areas very essential for construction industry of Bangladesh.

The development and dissemination of new construction equipment and better safety must be encouraged.

Pre-fabrication and use of package materials will enhance the efficiency of work execution by standardizing specifications and reduce the site work volumes.

The development and dissemination of all weather construction technology will make it possible to carry on with work even under bad weather.

The means of transferring information between designers and constructors need to be improved. The effective use of construction equipment, prefabricated materials and products needs to be considered.

The roles and responsibilities of engineers need to be reviewed with regard to improvements in work efficiency, personnel training and strengthening the management foundation of engineers.
5.2 Conclusion

Excavation

Manual excavation and excavation using excavator (5 to 20 ft depth) with different land areas were studied in Dhaka city. Considering labour cost and excavator rental charge, breakeven point for 5ft excavation and 20ft excavation are 19020sft and 3616sft respectively. Using PDW/97 standard rate of works, it is observed that for deeper excavation, excavator is cheaper than labor-intensive/manual excavation. Labor-intensive/manual excavation works may be acceptable outside urban areas due to unemployment of labor. But excavator is economic solution in urban areas like Dhaka city.

In Bangladesh, excavation and loading is a labour-based works but in developed countries its hardware-based works. Further detail study based on socio-economic, environment etc. may be required to introduce hardware-based excavation work replacing manual labor in our country.

Material

8 combinations of steel and concrete were studied for a six storied building. Considering material cost Type-1 (Combination of high strength concrete, 4.4-ksi with high strength steel, 60-ksi) is the most economic. Type-8 (a combination of low grade concrete, 2.5ksi and low grade steel, 40-ksi) is the most uneconomic, as it material costs 29% more than the cost due to the Type-1. Unfortunately Type-8 combination is most widely used in private construction even by the real estate developer. One problem with Type-1 is that high strength concrete (4.4 ksi concrete with 60 ksi steel) demands admixture, which also demand skilled humnware. If it is not possible, type 2 (3.6 ksi concrete with 60 ksi steel) can be easily used without loosing significant economy (only 3% more cost than Type-1). Mainly Engineers may play the significant role to convince owners/entrepreneur to accept this technological advantage and avoid uneconomical traditional approach.

5.3 Scope for Future Works

Similar studies may be carried out for other components of technology (namely different types of hardware technology, humnware, infoware, etc.)
REFERENCES


[8] Frank Harris: Modern Construction and Ground Engineering Equipment and Method

[9] V.K. Riana: Concrete bridge practice analysis, design and economics


[12] www.irco.com: Website


[17] Prospect of quality re-enforcement bar production in Bangladesh - Elite Iron and Steel Industries Ltd, 2003

APPENDIX-A

3-D Model, STAAD/Pro Input and Output (Partial)
APPENDIX-A

3-D Model, STAAD/Pro Input and Output (Partial)
3-D STAAD/Pro Model of Six Storied Building
**STAAD SPACE**

--- PAGE NO. ---

148. 271 272 276 277 320 329 341 PRIS YD 26 ZD 15

149. 9 14 15 63 64 70 71 86 87 94 95 110 111 152 167 158 208 209 22

150. 266 281 282 322 323 332 337 PRIS YD 23

151. 685 TO 922 902 TO 968 PRIS YD 10 ZD 23

152. 12 68 92 149 206 283 310 336 859 TO 866 PRIS YD 12 ZD 15

153. 9 16 65 72 88 96 112 153 169 210 225 287 283 324 333 338 PRIS YD 15

154. 11 67 90 114 171 228 285 335 843 TO 850 PRIS YD 40 ZD 10

155. 612 730 731 734 TO 736 748 749 756 TO 754 766 767 770 TO 772 802 803

156. 806 TO 808 834 PRIS YD 25 ZD 15

157. 577 580 618 PRIS YD 20 ZD 10

158. 501 TO 503 510 TO 512 517 TO 525 533 TO 535 542 TO 544 54

159. 558 TO 560 565 TO 567 574 TO 576 681 TO 593 590 TO 592 597 TO 599 60

160. 615 701 TO 703 710 711 714 715 719 TO 721 728 729 732 733 737 TO 735

161. 750 751 755 TO 757 764 765 768 769 773 TO 775 782 783 786 787 791 TO 767

162. 801 804 805 809 TO 811 818 822 823 833 832 PRIS YD 30 ZD 12

163. 593 790 PRIS YD 30 ZD 15

164. 596 PRIS YD 35 ZD 15

165. 504 TO 509 520 TO 525 526 TO 557 561 TO 557 568 TO 573 584 TO 589 61

166. 704 TO 709 722 TO 727 740 TO 745 758 TO 763 764 TO 781 794 TO 799 82

167. 826 PRIS YD 30 ZD 15

168. 600 TO 605 812 TO 817 PRIS YD 33 ZD 15

169. CONSTANTS

170. E CONCRETEMEMB 1 TO 16 28 TO 22 57 TO 72 74 TO 78 80 TO 90 92 TO 96

171. 98 TO 102 104 TO 114 149 TO 153 155 TO 159 161 TO 171 206 TO 210 212

172. 218 TO 228 263 TO 267 269 TO 273 275 TO 285 320 TO 324 326 TO 330 33

173. 340 TO 342 501 TO 518 701 TO 882 885 TO 892 895 TO 908

174. POISSON CONCRETE MEMB 1 TO 16 18 TO 22 57 TO 72 74 TO 78 80 TO 90 92

175. 98 TO 102 104 TO 114 149 TO 153 155 TO 159 161 TO 171 206 TO 210 212

176. 218 TO 228 263 TO 267 269 TO 273 275 TO 285 320 TO 324 326 TO 330 33

177. 340 TO 342 501 TO 518 701 TO 882 885 TO 892 895 TO 908

178. DENSITY CONCRETE MEMB 1 TO 16 18 TO 22 57 TO 72 74 TO 78 80 TO 90 92

179. 98 TO 102 104 TO 114 149 TO 153 155 TO 159 161 TO 171 206 TO 210 212

180. 218 TO 228 263 TO 267 269 TO 273 275 TO 285 320 TO 324 326 TO 330 33

181. 340 TO 342 501 TO 518 701 TO 882 885 TO 892 895 TO 908

182. ALPHA CONCRETE MEMB 1 TO 16 18 TO 22 57 TO 72 74 TO 78 80 TO 90 92

183. 98 TO 102 104 TO 114 149 TO 153 155 TO 159 161 TO 171 206 TO 210 212

184. 218 TO 228 263 TO 267 269 TO 273 275 TO 285 320 TO 324 326 TO 330 33

185. 340 TO 342 501 TO 613 701 TO 882 885 TO 892 895 TO 908

186. UNIT FEET KIP

187. SUPPORTS

188. 1 TO 16 18 TO 22 207 226 FIXED

189. 234 FIXED

190. 236 FIXED

191. DEFINE WIND LOAD

192. TYPE 1

193. INT 0 0.045 0.053 0.06 HEIG 10 30 60 90

194. EXP 1 JOINT 24 TO 184 192 TO 196 199 TO 202 205 206 208 TO 215 217 T

195. 237 TO 243

196. *EXCLUDE JOINT 46 69 92 115 138 161 184

197. LOAD 1 SELFWEIGHT

198. SELFWEIGHT Y = 1

199. LOAD 2 DEAD LOAD

200. FLOOR LOAD

201. * GROUND FLOOR IS A PARKING FLOOR
STAAD SPACE - PAGE NO

204. YRANGE 10 10 FLOAD -0.089
205. * 1ST FLOOR TO 5TH FLOOR IS OFFICE FLOOR + ROOF
206. * SELFWEIGHT = 0.068KSF, FLOOR FINISH = 0.02 KSF, FALSE CEILING = 0.
207. * NO OTHER LOAD AS FLOOR DEAD LOAD
208. YRANGE 20 70 FLOAD -0.104
209. * ROOF(EXTRA) AS GARDEN'3'0" SOIL IN PART OF THE ROOF
210. * SCIL = 0.3
211. * NO OTHER LOAD AS FLOOR DEAD LOAD
212. YRANGE 70 70 FLOAD -0.5 XRANGE 20 59.6 ZRANGE 21.33 70
213. *WATER TANK
214. YRANGE 80 80 FLOAD -0.5 XRANGE 59.8 69.73 ZRANGE 4.85 2
215. * ROOF SLAB .075KSF + .025 KSF
216. YRANGE 80 80 FLOAD -0.1
217. MEMBER LOAD
218. 701 702 719 720 737 738 755 756 774 791 792 809 810 UNI GY -0.43
219. LOAD 3 EXTERIOR WALL
220. MEMBER LOAD
221. **GROUND FLOOR TO 5TH FLOOR 5" WALL ASSUMED AT THE EXTERIOR OF THE
222. 501 TO 503 510 TO 519 526 TO 535 542 TO 551 558 TO 567 574 TO 583 55
223. 599 602 605 608 609 612 701 TO 703 710 TO 721 728 TO 739 746 TO 757
224. 764 775 782 TO 793 800 TO 808 813 TO 826 835 TO 841 851 TO 857 66
225. 875 TO 881 895 TO 901 UNI GY -0.5
226. LOAD 4 LIVE LOAD
227. FLOOR LOAD
228. **GROUND FLOOR AS GARRAGE
229. YRANGE 10 10 FLOAD -0.05
230. ** OFFICE SPACE AN AVERAGE OF 65LB/SFT
231. YRANGE 20 60 FLOAD -0.065
232. ** FOR PARTITION WALL(ACCIDENTAL LOAD)
233. YRANGE 20 60 FLOAD -0.04
234. *** ROOF OCCUPATIONAL LIVE LOAD OF 30 LB/SFT
235. YRANGE 70 70 FLOAD -0.03
236. *** ROOF LIVE LOAD OF 20 LB/SFT
237. YRANGE 80 80 FLOAD -0.02
238. MEMBER LOAD
239. 701 702 719 720 737 738 755 756 774 791 792 809 810 UNI GY -0.2
240. LOAD 5 WIND IN X
241. WIND LOAD X 1 TYPE 1
242. LOAD 6 WIND IN -X
243. WIND LOAD X -1 TYPE 1
244. LOAD 7 WIND IN Z
245. WIND LOAD Z 1 TYPE 1
246. LOAD 8 WIND IN Z
247. WIND LOAD Z -1 TYPE 1
248. LOAD COMB 21 UNFACTORED LOAD FOR GEO-TECH DESING
249. 1 1.0 2 1.0 3 1.0 4 1.0
250. LOAD COMB 22 FACTORED LOAD
251. 1 1.4 2 1.4 3 1.4 4 1.7
252. LOAD COMB 23 0.75(1.4DL+1.7LL+1.7WL X)
253. 1 1.05 2 1.05 3 1.05 4 1.275 5 1.275
254. LOAD COMB 24 0.75(1.4DL+1.7LL+1.7WL X)
255. 1 1.05 2 1.05 3 1.05 4 1.275 5 1.275
256. LOAD COMB 25 0.75(1.4DL+1.7LL+1.7WL 2)
257. 1 1.05 2 1.05 3 1.05 4 1.275 7 1.275
STAAD SPACE

260. LOAD COMB 27 0.9DL+1.3WL_X
261. 1 0.9 2 0.9 3 0.9 5 1.3
262. LOAD COMB 28 0.9DL+1.3WL_Y
263. 1 0.9 2 0.9 3 0.9 6 1.3
264. LOAD COMB 29 0.9DL+1.3WL_Z
265. 1 0.9 2 0.9 3 0.9 7 1.3
266. LOAD COMB 30 0.9DL+1.3WL_-Z
267. 1 0.9 2 0.9 3 0.9 8 1.3
268. PERFORM ANALYSIS

PROBLEM STATISTICS

NUMBER OF JOINTS/MEMBER-ELEMENTS/SUPPORTS = 228/ 479/ 25
ORIGINAL/FINAL BAND-WIDTH = 196/ 31
TOTAL PRIMARY LOAD CASES = 8, TOTAL DEGREES OF FREEDOM = 1218
SIZE OF STIFFNESS MATRIX = 226548 DOUBLE PREC. WORDS
REQD/AVAIL. DISK SPACE = 14.14/ 1130.8 MB, EXMEM = 1132.3 MB

++ Processing Element Stiffness Matrix. 10: 2:23
++ Processing Global Stiffness Matrix. 10: 2:23
++ Processing Triangular Factorization. 10: 2:23
++ Calculating Joint Displacements. 10: 2:24
++ Calculating Member Forces. 10: 2:24

269. LOAD LIST 21 22
270. ***
271. START CONCRETE DESIGN
272. CODE ACI
273. UNIT INCHES KIP
274. TRACK 2 ALL
275. MINMAIN 3 ALL
276. MAXMAIN 8 ALL
277. CLH 1.5 ALL
278. CLS 1.5 ALL
279. CLT 1.5 ALL
280. FC 2.5 ALL
281. FMAIN 40 ALL
282. DESIGN BEAM 501 TO 618 701 TO 842 851 TO 858 867 TO 982 895 TO 901
**CONCRETE TAKE OFF**

FOR BEAMS AND COLUMNS DESIGNED ABOVE

**TOTAL VOLUME OF CONCRETE = 11260.94 CU. FT**

<table>
<thead>
<tr>
<th>BAR SIZE</th>
<th>WEIGHT (in lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>18685.63</td>
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<tr>
<td>5</td>
<td>13536.21</td>
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<td>1084.97</td>
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<td>8</td>
<td>5565.20</td>
</tr>
</tbody>
</table>

*** TOTAL = 54729.96 ***

285. FINISH

**END OF STAAD-III**

**** DATE= JUN 29, 2003  TIME= 10: 3:41 ****

* FOR QUESTIONS REGARDING THIS VERSION OF PROGRAM *
* RESEARCH ENGINEERS, Inc at *
* West Coast: Ph- (714) 974-2500 Fax- (714) 971-2543 *
* East Coast: Ph- (978) 686-3626 Fax- (978) 685-7230 *

************************************************************************************************************************
PROBLEM STATISTICS

NUMBER OF JOINTS/MEMBER-ELEMENTS/SUPPORTS = 228/479/25
ORIGINAL/FINAL BAND-WIDTH = 196/31
TOTAL PRIMARY LOAD CASES = 8, TOTAL DEGREES OF FREEDOM = 1218
SIZE OF STIFFNESS MATRIX = 226548 DOUBLE PREC. WORDS
REQRD/AVAIL. DISK SPACE = 14.14/1157.0 MB, EXMEM = 1161.1 MB

++ Processing Element Stiffness Matrix. 16:35:42
++ Processing Global Stiffness Matrix. 16:35:42
++ Processing Triangular Factorization. 16:35:43
++ Calculating Joint Displacements. 16:35:43
++ Calculating Member Forces. 16:35:43

262. LOAD LIST 21 22
263. ****
264. START CONCRETE DESIGN
265. CODE ACI
266. UNIT INCHES KIP
267. TRACK 2 ALL
268. MINMAIN 4 ALL
269. MAXMAIN 8 ALL
270. CLB 1.5 ALL
271. CLS 1.5 ALL
272. CLT 1.5 ALL
273. FC 2.9 ALL
274. FYMAIN 40 ALL
275. DESIGN COLUMN 1 TO 16 18 TO 22 57 TO 72 74 TO 78 80 TO 90 92 TO 96 5
276. 104 TO 114 149 TO 153 155 TO 159 161 TO 171 206 TO 210 212 TO 216 23
277. 253 TO 267 269 TO 273 275 TO 285 320 TO 324 326 TO 330 332 TO 338 34
278. 343 TO 350 359 TO 366 385 TO 392 502 TO 508
PROBLEM STATISTICS

NUMBER OF JOINTS/MEMBER ELEMENTS SUPPORTS = 228 / 479 / 25
ORIGINAL/FINAL BAND WIDTH = 196 / 31
TOTAL PRIMARY LOAD CASES = 8. TOTAL DEGREES OF FREEDOM = 1218
SIZE OF STIFFNESS MATRIX = 226548 DOUBLE PREC. WORDS
REQD/AVAIL. DISK SPACE = 14.14/ 1130.9 MB. EXMEM = 1131.9 MB

++ Processing Element Stiffness Matrix. 10:16:46
++ Processing Global Stiffness Matrix. 10:16:46
++ Processing Triangular Factorization. 10:16:46
++ Calculating Joint Displacements. 10:16:47
++ Calculating Member Forces. 10:16:47

267. LOAD LIST 21 22
268. ****
269. START CONCRETE DESIGN
270. CODE ACI
271. UNIT INCHES KIP
272. TRACK 2 ALL
273. MINMAIN 3 ALL
274. MAXMAIN 8 ALL
275. CLB 1.5 ALL
276. CLS 1.5 ALL
277. CLT 1.5 ALL
278. FC 2.9 ALL
279. FYMAIN 40 ALL
280. DESIGN BEAM 501 TO 618 701 TO 842 851 TO 858 867 TO 882 895 TO 901
**Concrete Take Off**

(For beams and columns designed above)

**Total Volume of Concrete** - 10111.46 CU.FT

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight (in lbs)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1367.15</td>
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<td>8</td>
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---

283. Finish

*************** END OF STAAD-III ***************

**** DATE= JUN 29, 2003  TIME= 10:18:4 ****

* For questions regarding this version of program *
* Research Engineers, Inc at *
* West Coast: Ph- (714) 974-2500 Fax- (714) 971-2543 *
* East Coast: Ph- (978) 588-3626 Fax- (978) 585-7230 *

*******************************************************************************

C:AlexA_Arin/staad/ detail/VR/RC_10_19_Beam_VT.png

Page 495 of 495

A-13
STAAD SPACE

--- PAGE NO.

260. LOAD COMB 30 0.9DL+1.3WL - Z
261. 1 0.9 2 0.9 3 0.9 8 1.3
262. PERFORM ANALYSIS

PROBLEM STATISTICS

NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS = 228/ 479/ 25
ORIGINAL/FINAL BAND-WIDTH = 198/ 31
TOTAL PRIMARY LOAD CASES = 8, TOTAL DEGREES OF FREEDOM = 1218
SIZE OF STIFFNESS MATRIX = 226548 DOUBLE PREC. WORDS
REQUIRED/AVAIL. DISK SPACE = 14.141 996.6 MB, EXMEM = 999.5 MB

++ Processing Element Stiffness Matrix.
++ Processing Global Stiffness Matrix.
++ Processing Triangular Factorization.
++ Calculating Joint Displacements.
++ Calculating Member Forces.

263. LOAD LIST 21 22
264. ****
265. START CONCRETE DESIGN
266. CODE ACI
267. UNIT INCHES KIP
268. TRACK 2 ALL
269. MINMAIN 4 ALL
270. MAXMAIN 8 ALL
271. CLB 1.5 ALL
272. CLS 1.5 ALL
273. CLD 1.5 ALL
274. FC 2.5 ALL
275. FYMAIN 40 ALL
276. DESIGN COLUMN 1 TO 16 18 TO 22 57 TO 72 74 TO 76 80 TO 90 92 TO 96 5
277. 104 TO 149 TO 153 155 TO 159 161 TO 171 206 TO 210 212 TO 216 21
278. 263 TO 267 269 TO 273 275 TO 285 320 TO 324 326 TO 330 332 TO 338 34
279. 843 TO 850 859 TO 866 885 TO 892 902 TO 908

A-14
****** CONCRETE TAKES OFF ******
(FOR BEAMS AND COLUMNS DESIGNED ABOVE)

TOTAL VOLUME OF CONCRETE = 5055.26 CU.FT

<table>
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<tr>
<th>BAR SIZE</th>
<th>WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMBER</td>
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<tr>
<td>4</td>
<td>6601.82</td>
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<td>2505.57</td>
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<td>7067.75</td>
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<td>5216.26</td>
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<tr>
<td>8</td>
<td>8370.46</td>
</tr>
</tbody>
</table>

*** TOTAL= 29761.86

282. FINISH

****** END OF STAAD-III ******

**** DATE= JUN 26, 2003 TIME= 16:30: 4 ****

*******************************************************************************
* FOR QUESTIONS REGARDING THIS VERSION OF PROGRAM *
* RESEARCH ENGINEERS, Inc at *
* West Coast: Ph- (714) 974-2500 Fax- (714) 921-2543 *
* East Coast: Ph- (978) 688-3626 Fax- (978) 685-7230 *
*******************************************************************************
PROBLEM STATISTICS

NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS = 228/ 479/ 25
ORIGINAL/FINAL BAND-WIDTH = 196/ 31
TOTAL PRIMARY LOAD CASES = 8, TOTAL DEGREES OF FREEDOM = 1228
SIZE OF STIFFNESS MATRIX = 226548 DOUBLE PREC. WORDS
REQD/AVAIL. DISK SPACE = 14.14/ 1.129.8 MB, EXMEM = 1130.5 MB

++ Processing Element Stiffness Matrix. 10:49:36
++ Processing Global Stiffness Matrix. 10:49:36
++ Processing Triangular Factorization. 10:49:36
++ Calculating Joint Displacements. 10:49:37
++ Calculating Member Forces. 10:49:37

LOAD LIST 21 22
START CONCRETE DESIGN
CODE ACL
UNIT INCHES KIP
TRACK 2 ALL
MINMAIN 4 ALL
MAXMAIN 8 ALL
CLB 1.5 ALL
CLS 1.5 ALL
CLT 1.5 ALL
PC 4.4 ALL
FYMAIN 40 ALL
DESIGN COLUMN 1 TO 16 18 TO 22 57 TO 72 74 TO 78 80 TO 90 92 TO 96 5
104 TO 114 149 TO 153 155 TO 159 161 TO 171 206 TO 210 212 TO 216 21
263 TO 267 269 TO 273 275 TO 285 320 TO 324 326 TO 330 332 TO 338 34
843 TO 859 859 TO 865 885 TO 892 902 TO 908
****** CONCRETE TAKE OFF ******
(FOR BEAMS AND COLUMNS DESIGNED ABOVE)

TOTAL VOLUME OF CONCRETE = 3498.73 CU.FT

<table>
<thead>
<tr>
<th>BAR SIZE NUMBER</th>
<th>WEIGHT (in lbs)</th>
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<tbody>
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<td>4</td>
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<tr>
<td>5</td>
<td>1358.06</td>
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<tr>
<td>6</td>
<td>1434.47</td>
</tr>
<tr>
<td>7</td>
<td>2587.75</td>
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<tr>
<td>8</td>
<td>7726.58</td>
</tr>
</tbody>
</table>

*** TOTAL= 21787.04

281. FINISH

****** END OF STAAD-III ******

*** DATE= JUN 29,2003  TIME= 10:49:39 ***

******************************************************************************************************************************************************************************
* FOR QUESTIONS REGARDING THIS VERSION OF PROGRAM *
* RESEARCH ENGINEERS, Inc at *
* West Coast: Ph- (714) 974-2500 Fax- (714) 921-2543 *
* East Coast: Ph- (978) 688-3626 Fax- (978) 685-7230 *
******************************************************************************************************************************************************************************
STAAD SPACE

260. 1 1.05 2 1.05 3 1.05 4 1.275 E 1.275
261. LOAD COMB 27 0.9DL+1.3WL_X
262. 1 0.9 2 0.9 3 0.9 5 1.3
263. LOAD COMB 28 0.9DL+1.3WL_-X
264. 1 0.9 2 0.9 3 0.9 5 1.3
265. LOAD COMB 29 0.9DL+1.3WL_Z
266. 1 0.9 2 0.9 3 0.9 7 1.3
267. LOAD COMB 30 0.9DL+1.3WL_-Z
268. 1 0.9 2 0.9 3 0.9 8 1.3
269. PERFORM ANALYSIS

PROBLEM STATISTICS

NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS = 228/ 479/ 25
ORIGINAL/FINAL BAND-WIDTH = 196/ 31
TOTAL PRIMARY LOAD CASES = 8, TOTAL DEGREES OF FREEDOM = 1218
SIZE OF STIFFNESS MATRIX = 226548 DOUBLE PREC. WORDS
REQD/AVAIL. DISK SPACE = 14.14/ 1005.2 MB, EXMEM = 1007.4 MB

++ Processing Element Stiffness Matrix.  11:57:49
++ Processing Global Stiffness Matrix.  11:57:49
++ Processing Triangular Factorization.  11:57:49
++ Calculating Joint Displacements.  11:57:50
++ Calculating Member Forces.  11:57:50

270. LOAD LIST 21 22
271. ****
272. START CONCRETE DESIGN
273. CODE ACI
274. UNIT INCHES KIP
275. TRACK 2 ALL
276. MINMAIN 9 ALL
277. MAXMAIN 9 ALL
278. CLM 1.5 ALL
279. GLS 1.5 ALL
280. CLT 1.5 ALL
281. FC 4.4 ALL
282. FYMAIN 40 ALL
283. DESIGN BEAM 501 TO 618 701 TO 842 851 TO 858 857 TO 882 895 TO 901
*************** CONCRETE TAKE OFF ***************
(FOR BEAMS AND COLUMNS DESIGNED ABOVE)

TOTAL VOLUME OF CONCRETE = 8545.55 CU.FT

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<td>17628.84</td>
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<tr>
<td>5</td>
<td>4877.50</td>
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<tr>
<td>6</td>
<td>7744.93</td>
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<td>7</td>
<td>792.14</td>
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<tr>
<td>8</td>
<td>16894.94</td>
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*** TOTAL = 47938.25

286. FINISH

*************** END OF STAAD-III ***************

**** DATE= JUN 29, 2003 TIME= 11:59:10 ****

*******************************************************************************
* FOR QUESTIONS REGARDING THIS VERSION OF PROGRAM *
* RESEARCH ENGINEERS, Inc at *
* West Coast: Ph- (714) 974-2500 Fax- (714) 921-2543 *
* East Coast: Ph- (978) 688-3626 Fax- (978) 685-7230 *
*******************************************************************************
STAAD SPACE

260. LOAD COMB 30 0.9DL+1.3WL+2
261. 1 0.9 2 0.9 3 0.9 8 1.3
262. PERFORM ANALYSIS

PROBLEM STATISTICS

NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS = 228/ 479/ 25
ORIGINAL/FINAL BAND-WIDTH = 196/ 31
TOTAL PRIMARY LOAD CASES = 8, TOTAL DEGREES OF FREEDOM = 1218
SIZE OF STIFFNESS MATRIX = 226548 DOUBLE PREC. WORDS
REQD/AVAIL. DISK SPACE = 14.14/ 1129.7 MB, EXEMEM = 1132.2 MB

++ Processing Element Stiffness Matrix. 9:28:33
++ Processing Global Stiffness Matrix. 9:28:23
++ Processing Triangular Factorization. 9:28:23
++ Calculating Joint Displacements. 9:28:24
++ Calculating Member Forces. 9:28:24

263. LOAD LIST 21 22
264. ****
265. START CONCRETE DESIGN
266. CODE ACI
267. UNIT INCHES KIP
268. TRACK 2 ALL
269. MINMAIN 4 ALL
270. MAXMAIN 8 ALL
271. CLB 1.5 ALL
272. CLS 1.5 ALL
273. CLT 1.5 ALL
274. FC 3.6 ALL
275. FYMAIN 40 ALL
276. DESIGN COLUMN 1 TO 16 18 TO 22 57 TO 72 74 TO 78 80 TO 92 TO 96 5
277. 104 TO 114 149 TO 153 155 TO 159 161 TO 171 206 TO 210 212 TO 216 21
278. 253 TO 267 269 TO 273 275 TO 285 320 TO 324 326 TO 330 332 TO 336 34
279. 843 TO 850 859 TO 866 885 TO 892 902 TO 908
************ CONCRETE TAKE OFF ************
(FOR BEAMS AND COLUMNS DESIGNED ABOVE)

TOTAL VOLUME OF CONCRETE = 3478.91 CU.FT

<table>
<thead>
<tr>
<th>BAR SIZE NUMBER</th>
<th>WEIGHT (in lbs)</th>
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<tbody>
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<td>5</td>
<td>1431.75</td>
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<td>6</td>
<td>3795.37</td>
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<td>4686.48</td>
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<td>8</td>
<td>9067.99</td>
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</table>

*** TOTAL = 26751.64

282. FINISH

************ END OF STAAD-III ************

**** DATE = JUN 29, 2003 TIME = 9:29:25 ****

FOR QUESTIONS REGARDING THIS VERSION OF PROGRAM

* RESEARCH ENGINEERS, INC at
* West Coast: Ph- (714) 974-2500 Fax- (714) 921-2543 *
* East Coast: Ph- (978) 588-3626 Fax- (978) 685-7230 *

******************************************************************************
STAAD SPACE

260. 1 1.05 2 1.05 3 1.05 4 1.275 7 1.275
261. LOAD COMB 26 0.75(1.4DL+1.7LL+1.7WL -Z)
262. 1 1.05 2 1.05 3 1.05 4 1.275 8 1.275
263. LOAD COMB 27 0.9DL+1.3WL_X
264. 1 0.9 2 0.9 3 0.9 5 1.3
265. LOAD COMB 28 0.9DL+1.3WL_X
266. 1 0.9 2 0.9 3 0.9 6 1.3
267. LOAD COMB 29 0.9DL+1.3WL_Z
268. 1 0.9 2 0.9 3 0.9 7 1.3
269. LOAD COMB 30 0.9DL+1.3WL_Z
270. 1 0.9 2 0.9 3 0.9 8 1.3
271. PERFORM ANALYSIS

PROBLEM STATISTICS

----------------------
NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS = 228/ 479/ 25
ORIGINAL/FINAL BAND-WIDTH = 196/ 31
TOTAL PRIMARY LOAD CASES = 8, TOTAL DEGREES OF FREEDOM = 1218
SIZE OF STIFFNESS MATRIX = 226548 DOUBLE PREC. WORDS
REQRD/AVAIL. DISK SPACE = 14.14/ 1126.8 MB, EXMEM = 1132.5 MB

++ Processing Element Stiffness Matrix. 9:51:34
++ Processing Global Stiffness Matrix. 9:51:34
++ Processing Triangular Factorization. 9:51:34
, ++ Calculating Joint Displacements. 9:51:35
++ Calculating Member Forces. 9:51:35

272. LOAD LIST 21 22
273. ****
274. START CONCRETE DESIGN
275. CODE ACI
276. UNIT INCHES KIP
277. TRACK 2 ALL
278. MINMAIN 3 ALL
279. MAXMAIN 8 ALL
280. CLB 1.5 ALL
281. CLS 1.5 ALL
282. CLT 1.5 ALL
283. FC 3.6 ALL
284. FYMAIN 40 ALL
285. DESIGN BEAM 501 TO 618 701 TO 842 851 TO 858 867 TO 882 895 TO 901

C:\AIAH_A32P\staad\GEUSD벨V\BEC 40.16_Beam_VL.xls  Page 7 of 48
A-22
CONCRETE TAKE OFF

(FOR BEAMS AND COLUMNS DESIGNED ABOVE)

TOTAL VOLUME OF CONCRETE = 9643.74 CU.FT

<table>
<thead>
<tr>
<th>BAR SIZE NUMBER</th>
<th>WEIGHT (in lbs)</th>
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<tbody>
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<td>17704.71</td>
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<td>5</td>
<td>15511.37</td>
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<tr>
<td>6</td>
<td>13077.93</td>
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<td>11522.34</td>
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<tr>
<td>8</td>
<td>16674.96</td>
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</tbody>
</table>

*** TOTAL = 50203.31

FINISH

END OF STAAD-III

**** DATE = JUN 29, 2001 TIME = 9:52:52 ****

FOR QUESTIONS REGARDING THIS VERSION OF PROGRAM RESEARCH ENGINEERS, Inc at
West Coast: Ph- (714) 974-2500 Fax- (714) 921-2543
East Coast: Ph- (978) 688-3626 Fax- (978) 685-7230
STAAD SPACE

260. LOAD COMB 29 0.9DL+1.3WL Z
261. 1 0.9 2 0.9 3 0.9 7 1.3
262. LOAD COMB 30 0.9DL+1.3WL _Z
263. 1 0.9 2 0.9 3 0.9 8 1.3
264. PERFORM ANALYSIS

PROBLEM STATISTICS

NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS = 228 / 479 / 25
ORIGINAL/FINAL BAND-WIDTH = 196 / 31
TOTAL PRIMARY LOAD CASES = 8, TOTAL DEGREES OF FREEDOM = 1218
SIZE OF STIFFNESS MATRIX = 226548 DOUBLE PREC. WORDS
REQED/AVAIL. DISK SPACE = 14.14 / 1235.3 MB, EXMEM = 1138.0 MB

15:19:59 ++ Processing Global Stiffness Matrix.
15:19:59 ++ Processing Triangular Factorization
15:20:0 ++ Calculating Member Forces.

265. LOAD LIST 21 22
266. ****
267. START CONCRETE DESIGN
268. CODE ACI
269. UNIT INCHES KIP
270. TRACK 2 ALL
271. MINMAIN 4 ALL
272. MAXMAIN 8 ALL
273. CLB 1.5 ALL
274. CLS 1.5 ALL
275. CLT 1.5 ALL
276. FC 1.4 ALL
277. FVMAIN 60 ALL

278. DESIGN COLUMN 1 TO 16 18 TO 22 57 TO 72 74 TO 78 80 TO 92 TO 96 5
279. 104 TO 114 149 TO 153 155 TO 159 161 TO 172 206 TO 210 212 TO 216 21
280. 263 TO 267 269 TO 273 275 TO 285 320 TO 324 326 TO 330 332 TO 338 34
281. 343 TO 850 859 TO 866 885 TO 892 902 TO 908

C:\AIA\A_ASTM\models\VORDAEQ.GNU\BEC_60 #1_columns_2L.snl
*************** CONCRETE TAKE OFF  ***************
(FOR BEAMS AND COLUMNS DESIGNED ABOVE)

TOTAL VOLUME OF CONCRETE = 2868.75 CU.FT

<table>
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<th>BAR SIZE NUMBER</th>
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<tbody>
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<td>1385.57</td>
</tr>
<tr>
<td>8</td>
<td>3970.60</td>
</tr>
</tbody>
</table>

*** TOTAL= 19365.35

284. FINISH

*************** END OF STAAD-III  ***************

*** DATE= JUN 25, 2003  TIME= 15:21:17 ***
STAAD SPACE

261. LOAD COMB 24 0.75(1.4DL+1.7LL+1.7WL_X)
262. 1 1.05 2 1.05 3 1.05 4 1.275 6 1.275
263. LOAD COMB 25 0.75(1.4DL+1.7LL+1.7WL_Z)
264. 1 1.05 2 1.05 3 1.05 4 1.275 7 1.275
265. LOAD COMB 26 0.75(1.4DL+1.7LL+1.7WL_Z)
266. 1 1.05 2 1.05 3 1.05 4 1.275 8 1.275
267. LOAD COMB 27 0.9DL+1.3WL_X
268. 1 0.9 2 0.9 3 0.9 5 1.3
269. LOAD COMB 28 0.9DL+1.3WL_X
270. 1 0.9 2 0.9 3 0.9 5 1.3
271. LOAD COMB 29 0.9DL+1.3WL_Z
272. 1 0.9 2 0.9 3 0.9 7 1.3
273. LOAD COMB 30 0.9DL+1.3WL_Z
274. 1 0.9 2 0.9 3 0.9 8 1.3
275. PERFORM ANALYSIS

PROBLEM STATISTICS

NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS = 228/479/25
ORIGINAL/FINAL BAND-WIDTH = 196/31
TOTAL PRIMARY LOAD CASES = 8, TOTAL DEGREES OF FREEDOM = 1218
SIZE OF STIFFNESS MATRIX = 226548 DOUBLE PREC. WORDS
REQ'D/AVAIL. DISK SPACE = 14.14/1136.2 MB, EXEM = 1138.4 MB

++ Processing Element Stiffness Matrix. 15:47:53
++ Processing Global Stiffness Matrix. 15:47:53
++ Processing Triangular Factorization. 15:47:53
++ Calculating Joint Displacements. 15:47:53
++ Calculating Member Forces. 15:47:54

276. LOAD LIST 21 22
277. ****
278. START CONCRETE DESIGN
279. CODE ACI
280. UNIT INCHES KIP
281. TRACK 2 ALL
282. MINMAIN 4 ALL
283. MAXMAIN 8 ALL
284. CLB 1.5 ALL
285. CLS 1.5 ALL
286. CLT 1.5 ALL
287. FC 4.4 ALL
288. FMMAIN 60 ALL
289. DESIGN BEAM 501 TO 616 701 TO 842 851 TO 858 867 TO 882 895 TO 901
*************** CONCRETE TAKE OFF  ***************

(TOTAL VOLUME OF CONCRETE = 6145.43 CU.FT)

<table>
<thead>
<tr>
<th>BAR SIZE</th>
<th>WEIGHT (in lbs)</th>
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<tbody>
<tr>
<td>4</td>
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<td>5329.07</td>
</tr>
<tr>
<td>7</td>
<td>5487.20</td>
</tr>
<tr>
<td>8</td>
<td>10511.19</td>
</tr>
</tbody>
</table>

*** TOTAL= 46517.38

292. FINISH

*************** END OF STAAD-III  ***************

**** DATE= JUN 25, 2003  TIME= 15:49:29 ****

* FOR QUESTIONS REGARDING THIS VERSION OF PROGRAM *
* RESEARCH ENGINEERS, Inc at *
* West Coast: Ph- (714) 974-2500  Fax- (714) 921-2543 *
* East Coast: Ph- (978) 688-3626  Fax- (978) 685-7230 *

***************************************************************************
260. 1 0.9 2 0.9 3 0.9 7 1.3
261. LOAD COMB 30 0.9DL+1.3WL_Z
262. 1 0.9 2 0.9 3 0.9 8 1.3
263. PERFORM ANALYSIS

**PROBLEM STATISTICS**

NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS = 228/ 479/ 25
ORIGINAL/FINAL BAND-WIDTH = 196/ 31
TOTAL PRIMARY LOAD CASES = 8, TOTAL DEGREES OF FREEDOM = 1218
SIZE OF STIFFNESS MATRIX = 226548 DOUBLE PREC. WORDS
REQUIRED/AVAIL. DISK SPACE = 14.14/ 847.1 MB, EXMEM = 860.0 MB

++ Processing Element Stiffness Matrix. 12: 1:32
++ Processing Global Stiffness Matrix. 12: 1:32
++ Processing Triangular Factorization 12: 1:32
++ Calculating Joint Displacements. 12: 1:33
++ Calculating Member Forces. 12: 1:33

264. LOAD LIST 21 22
265. ****
266. START CONCRETE DESIGN
267. CODE ACI
268. UNIT INCHES KIP
269. TRACK 2 ALL
270. MINMAIN 4 ALL
271. MAXMAIN 8 ALL
272. CLB 1.5 ALL
273. CLS 1.5 ALL
274. CLT 1.5 ALL
275. FC 3.6 ALL
276. FYMAIN 60 ALL
277. DESIGN COLUMN 1 TO 16 18 TO 22 57 TO 72 74 TO 76 80 TO 90 92 TO 96 5
278. 104 TO 114 149 TO 153 155 TO 159 161 TO 171 206 TO 210 212 TO 216 21
279. 263 TO 267 269 TO 273 275 TO 285 328 TO 324 326 TO 330 332 TO 338 34
280. 843 TO 850 859 TO 868 885 TO 892 902 TO 903
CONCRETE TAKE OFF

(FOR BEAMS AND COLUMNS DESIGNED ABOVE)

TOTAL VOLUME OF CONCRETE = 3354.74 CU.FT

<table>
<thead>
<tr>
<th>BAR SIZE</th>
<th>WEIGHT (in lbs)</th>
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</thead>
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<tr>
<td>5</td>
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<td>2771.14</td>
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<tr>
<td>8</td>
<td>4721.80</td>
</tr>
</tbody>
</table>

*** TOTAL = 21120.07

28.3. FINISH

END OF STAAD-III
STAAD SPACE

260. 1 0.9 2 0.9 3 0.9 5 1.3
261. LOAD COMB 28 0.9DL+1.3WL-X
262. 1 0.9 2 0.9 3 0.9 6 1.3
263. LOAD COMB 29 0.9DL+1.3WL-Z
264. 1 0.9 2 0.9 3 0.9 7 1.3
265. LOAD COMB 30 0.9DL+1.3WL-Z
266. 1 0.9 2 0.9 3 0.9 8 1.3
267. PERFORM ANALYSIS

PROBLEM STATISTICS

NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS = 228/ 479/ 25
ORIGINAL/FINAL BAND-WIDTH = 196/ 31
TOTAL PRIMARY LOAD CASES = 8, TOTAL DEGREES OF FREEDOM = 1218
SIZE OF STIFFNESS MATRIX = 226548 DOUBLE PREC. WORDS
REQRD/AVAIL. DISK SPACE = 14.14/ 851.1 MB, EXMEM = 857.9 MB

++ Processing Element Stiffness Matrix. 11:41:25
++ Processing Global Stiffness Matrix. 11:41:25
++ Processing Triangular Factorization. 11:41:26
++ Calculating Joint Displacements. 11:41:26
++ Calculating Member Forces. 11:41:27

268. LOAD LIST 21 22
269. ***
270. START CONCRETE DESIGN
271. CODE ACI
272. UNIT INCHES KIP
273. TRACK 2 ALL
274. MINMAIN 4 ALL
275. MAXMAIN 8 ALL
276. CLB 1.5 ALL
277. CLS 1.5 ALL
278. CLT 1.5 ALL
279. FC 3.6 ALL
280. FYMAIN 60 ALL
281. DESIGN BEAM 501 TO 518 701 TO 842 851 TO 867 882 TO 895 TO 901
*************** CONCRETE TAKE OFF ****************
(FOR BEAMS AND COLUMNS DESIGNED ABOVE)

TOTAL VOLUME OF CONCRETE = 7278.73 CU. FT

<table>
<thead>
<tr>
<th>BAR SIZE</th>
<th>WEIGHT (in lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>22347.70</td>
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<td>6654.93</td>
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<td>4000.96</td>
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<tr>
<td>8</td>
<td>5049.18</td>
</tr>
</tbody>
</table>

*** TOTAL= 44092.00

284. FINISH

*************** END OF STAAD-III ***************

**** DATE= JUN 28, 2003  TIME= 11:43: 5 ****

* FOR QUESTIONS REGARDING THIS VERSION OF PROGRAM *
* RESEARCH ENGINEERS, Inc at *
* West Coast: Ph- (714) 974-2500 Fax- (714) 921-2543 *
* East Coast: Ph- (978) 688-3626 Fax- (978) 685-7230 *

******************************************************************************
STAAD SPACE

252. 1 1.4 2 1.4 3 1.4 4 1.7
253. LOAD COMB 23 0.75 (1.4DL+1.7LL+1.7WL_X)
254. 1 1.05 2 1.05 3 1.05 4 1.275 5 1.275
255. LOAD COMB 24 0.75 (1.4DL+1.7LL+1.7WL_-X)
256. 1 1.05 2 1.05 3 1.05 4 1.275 6 1.275
257. LOAD COMB 25 0.75 (1.4DL+1.7LL+1.7WL_Z)
258. 1 1.05 2 1.05 3 1.05 4 1.275 7 1.275
259. LOAD COMB 26 0.75 (1.4DL+1.7LL+1.7WL_-Z)
260. 1 1.05 2 1.05 3 1.05 4 1.275 8 1.275
261. LOAD COMB 27 0.9DL+1.3WL_X
262. 1 0.9 2 0.9 3 0.9 5 1.3
263. LOAD COMB 28 0.9DL+1.3WL_-X
264. 1 0.9 2 0.9 3 0.9 6 1.3
265. LOAD COMB 29 0.9DL+1.3WL_Z
266. 1 0.9 2 0.9 3 0.9 7 1.3
267. LOAD COMB 30 0.9DL+1.3WL_-Z
268. 1 0.9 2 0.9 3 0.9 8 1.3
269. PERFORM ANALYSIS

PROBLEM STATISTICS

NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS = 228/ 479/ 25
ORIG/FINAL BAND-WIDTH = 196/ 31
TOTAL PRIMARY LOAD CASES = 8, TOTAL DEGREES OF FREEDOM = 1218
SIZE OF STIFFNESS MATRIX = 226548 DOUBLE PREC. WORDS
REQD/AVAIL. DISK SPACE = 14.14/ 1156.9 MB, EXMMEM = 1160.7 MB

++ Processing Element Stiffness Matrix. 16:59:23
++ Processing Global Stiffness Matrix. 16:59:23
++ Processing Triangular Factorization. 16:59:23
++ Calculating Joint Displacements. 16:59:24
++ Calculating Member Forces. 16:59:24

270. LOAD LIST 21 22
271. ****
272. START CONCRETE DESIGN
273. CODE ACI
274. UNIT INCHES KIP
275. TRACK 2 ALL
276. MINMAIN 4 ALL
277. MAXMAIN 8 ALL
278. CLB 1.5 ALL
279. CLS 1.5 ALL
280. CLT 1.5 ALL
281. FC 2.9 ALL
282. FMAIN 60 ALL
283. DESIGN COLUMN 1 TO 16 18 TO 22 57 TO 72 74 TO 78 80 TO 90 92 TO 96 98
284. 104 TO 114 149 TO 153 155 TO 159 161 TO 172 206 TO 210 212 TO 216 218
285. 263 TO 267 269 TO 273 275 TO 285 320 TO 324 326 TO 330 332 TO 338 34
*************** CONCRETE TAKE OFF ***************
(For beams and columns designed above)

Total volume of concrete = 3527.61 cu.ft

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Weight (in lbs)</th>
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<tbody>
<tr>
<td>4</td>
<td>7671.93</td>
</tr>
<tr>
<td>5</td>
<td>2969.84</td>
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<tr>
<td>7</td>
<td>5725.66</td>
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<tr>
<td>8</td>
<td>5875.42</td>
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*** Total = 26213.38

289. Finish

*************** END OF STAAD-III ***************

**** Date: Jun 19, 2003  Time: 17:02:27 ****

* For questions regarding this version of program *
* Research Engineers, Inc at *
* West Coast: Ph- (714) 274-2500 Fax- (714) 251-1254 *
* East Coast: Ph- (978) 688-3626 Fax- (978) 685-7230 *

****
STAAND SPACE

PROBLEM STATISTICS

NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS = 228/ 479/ 25
ORIGINAL/FINAL BAND-WIDTH = 196/ 31
TOTAL PRIMARY LOAD CASES = 8, TOTAL DEGREES OF FREEDOM = 1218
SIZE OF STIFFNESS MATRIX = 226548 DOUBLE PREC. WORDS
REQD/AVAIL. DISK SPACE = 14.14/ 1162.2 MB, EXMEM = 1163.0 MB

++ Processing Element Stiffness Matrix. 16: 4:45
++ Processing Global Stiffness Matrix. 15: 4:45
++ Processing Triangular Factorization. 15: 4:45
++ Calculating Joint Displacements. 15: 4:45
++ Calculating Member Forces. 16: 4:46

252. LOAD COMB 24 0.75 (1.4DL+1.7LL+1.7WL-X)
253. LOAD COMB 25 0.75 (1.4DL+1.7LL+1.7WL-Z)
254. LOAD COMB 26 0.75 (1.4DL+1.7LL+1.7WL-Z)
255. LOAD COMB 27 0.9DL+1.3WL_X
256. LOAD COMB 28 0.9DL+1.3WL_X
257. LOAD COMB 29 0.9DL+1.3WL_Z
258. LOAD COMB 30 0.9DL+1.3WL_Z
259. PERFORM ANALYSIS

260. LOAD LIST 21 TO 22
261. **
262. START CONCRETE DESIGN
263. CODE ACI
264. TRACK 2
265. MINMAIN 4 ALL
266. MAXMAIN 8 ALL
267. CLB 1.5
268. CLS 1.5
269. CLT 1.5
270. FC 2.9
271. FYMAIN 60
272. DESIGN BEAM 501 TO 618 701 TO 842 851 TO 858 867 TO 892 895 TO 901
*************** CONCRETE TAKE OFF ***************
(FOR BEAMS AND COLUMNS DESIGNED ABOVE)

TOTAL VOLUME OF CONCRETE = 9366.63 CU.FT

<table>
<thead>
<tr>
<th>BAR SIZE</th>
<th>WEIGHT (in lbs)</th>
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<td>22181.96</td>
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<tr>
<td>5</td>
<td>10010.75</td>
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<td>6</td>
<td>3765.23</td>
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<td>7</td>
<td>6918.01</td>
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<td>8</td>
<td>342.97</td>
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</tbody>
</table>

*** TOTAL: 43218.92

284. FINISH

*************** END OF STAAD-III ***************


* FOR QUESTIONS REGARDING THIS VERSION OF PROGRAM *
* RESEARCH ENGINEERS, Inc at *
* West Coast: Ph- (714) 974-2500 Fax- (714) 921-2543 *
* East Coast: Ph- (978) 688-3626 Fax- (978) 685-7230 *

*******************************************************************************************
**Problem Statistics**

---

**Number of Joints/Member+Elements/Supports:** 228/479/25

**Original/Final Band-Width:** 196/31

**Total Primary Load Cases:** 8, **Total Degrees of Freedom:** 1218

**Size of Stiffness Matrix:** 226548 Double PreC. Words

**Reqd/Aval. Disk Space:** 14.14/1057.0 MB, **Exmem:** 1059.7 MB

++ Processing Element Stiffness Matrix. 12:25:48
++ Processing Global Stiffness Matrix. 12:35:48
++ Processing Triangular Factorization. 12:35:48
++ Calculating Joint Displacements. 12:35:49
++ Calculating Member Forces. 12:35:49
*************** CONCRETE TAKE OFF ***************

(FOR BEAMS AND COLUMNS DESIGNED ABOVE)

TOTAL VOLUME OF CONCRETE = 4189.98 CU.FT

<table>
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<th>BAR SIZE</th>
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<tbody>
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<td>9556.34</td>
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<td>5</td>
<td>2452.93</td>
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<td>6</td>
<td>3610.31</td>
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<td>7</td>
<td>6377.59</td>
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<tr>
<td>8</td>
<td>6760.75</td>
</tr>
</tbody>
</table>

*** TOTAL= 28958.03

286. FINISH

*************** END OF STAAD-III ***************

**** DATE= JUN 28,2003 TIME= 12:37:11 ****

******************************************************************************
* FOR QUESTIONS REGARDING THIS VERSION OF PROGRAM *
* RESEARCH ENGINEERS, Inc at *
* West Coast: Ph- (714) 974-2500 Fax- (714) 921-2543 *
* East Coast: Ph- (978) 688-3626 Fax- (978) 685-7230 *
******************************************************************************
STAAD SPACE

260. 1 1.05 2 1.65 3 1.05 4 1.275 8 1.275
261. LOAD COMB 27 0.9DL+1.3WL_X
262. 1 0.9 2 0.9 3 0.9 5 1.3
263. LOAD COMB 28 0.9DL+1.3WL_-X
264. 1 0.9 2 0.9 3 0.9 6 1.3
265. LOAD COMB 29 0.9DL+1.3WL_Z
266. 1 0.9 2 0.9 3 0.9 7 1.3
267. LOAD COMB 30 0.9DL+1.3WL_-Z
268. 1 0.9 2 0.9 3 0.9 8 1.3
269. PERFORM ANALYSIS

PROBLEM STATISTICS

NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS = 228/ 479/ 25
ORIGINAL/FINAL BAND-WIDTH = 196/ 31
TOTAL PRIMARY LOAD CASES = 8, TOTAL DEGREES OF FREEDOM = 1118
SIZE OF STIFFNESS MATRIX = 226548 DOUBLE PREC. WORDS
REQD/AVAIL. DISK SPACE = 14.14/1130.9 MB, EXMEM = 1131.9 MB

++ Processing Element Stiffness Matrix. 10:33: 9
++ Processing Global Stiffness Matrix. 10:33: 9
++ Processing Triangular Factorization. 10:33: 9
++ Calculating Joint Displacements. 10:33:10
++ Calculating Member Forces. 10:33:10

270. LOAD LIST 21 22
271. ****
272. START CONCRETE DESIGN
273. CODE ACI
274. UNIT INCHES KIP
275. TRACK 2 ALL
276. MINMAIN 4 ALL
277. MAXMAIN 8 ALL
278. CLB 1.5 ALL
279. CLS 1.5 ALL
280. CLT 1.5 ALL
281. FC 2.5 ALL
282. FYMAIN 60 ALL
283. DESIGN BEAM 501 TO 618 701 TO 842 851 TO 858 867 TO 882 895 TO 901
**CONCRETE TAKE OFF**

(FOR BEAMS AND COLUMNS DESIGNED ABOVE)

TOTAL VOLUME OF CONCRETE = 10076.25 CU.FT

<table>
<thead>
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<td>6</td>
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<td>30007.63</td>
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<td>702.99</td>
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</table>

*** TOTAL= 43733.00

286. FINISH

************* END OF STAAD-III *************

**** DATE= JUN 29, 2003  TIME= 16:34:28 ****

* FOR QUESTIONS REGARDING THIS VERSION OF PROGRAM  *
* RESEARCH ENGINEERS, Inc at *
* West Coast: Ph- (714) 974-2500  Fax- (714) 923-2543 *
* East Coast: Ph- (978) 685-3626  Fax- (978) 685-7230 *

**************************************************************************
APPENDIX-B

List of Buildings for Different Strength Concrete and Reinforcement
<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>DEVELOPER</th>
<th>CONCRETE STRENGTH</th>
<th>STEEL STRENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>6(SIX) STORIED RESIDENTIAL BUILDING.</td>
<td>ABC REAL ESTATES LTD</td>
<td>3000 psi</td>
<td>60000 psi</td>
</tr>
<tr>
<td>AT PLOT NO. 23/9, KHELGI ROAD BLOCK-B, MOHAMMADPUR HOUSING ESTATE, MOHAMMADPUR, DHAKA</td>
<td>ABC HOUSE (5TH FLOOR), 8 KAMAL ATATURK AVENUE, DHAKA-1205</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9(NINE) STORIED RESIDENTIAL BUILDING.</td>
<td>MONICO LIMITED</td>
<td>3000 psi</td>
<td>60000 psi</td>
</tr>
<tr>
<td>AT PLOT NO. 507, MOUZA KAFRUL, WEST AGARGAON, DHAKA</td>
<td>HOUSE NO 71/1, ROAD NO 7/A, DHANMONDI R/A, DHAKA-1209</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9(SIX) STORIED RESIDENTIAL BUILDING.</td>
<td>MR. MOHAMMAD HABIBUR RAHMAN</td>
<td>2500 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>AT BAFTUL AMAN CO-OPERATIVE HOUSING SOCIETY LIMITED, PLOT NO-578, CS NO-124, KHATIAN NO-34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6(SIX) STORIED CHAMPA SUPER MARKET</td>
<td>M/S NISHA CONSTRUCTION</td>
<td>2500 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>AT BAJIAKANDI BAZAR, BAJIAKANDI, RAJBARI</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5(FIVE) STORIED ADMIN BUILDING OF MANSHUR ALI COLLEGE</td>
<td>M/S NISHA CONSTRUCTION</td>
<td>2500 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>AT NARUA BAJIAKANDI, RAJBARI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 STORIED MINNAT PLAZA</td>
<td>MD. MINNAT HOSSAIN</td>
<td>2500 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>A SHOPPING CUM RESIDENTIAL BUILDING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AT ABDULLAHPUR KERANIGONJ, DHAKA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WELKIN'S CANOPUS</td>
<td>WELKIN'S PROPERTY MANAGEMENT LTD</td>
<td>2500 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>9 STORIED APARTMENT BUILDING</td>
<td>43/D, AMIRBAG R/A, MEHEDIBAGI CHITTAGONG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AT LALKHAN BAZAR, CHITTAGONG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WELKIN'S CALYX</td>
<td>WELKIN'S PROPERTY MANAGEMENT LTD</td>
<td>2500 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>9 STORIED APARTMENT BUILDING</td>
<td>43/D, AMIRBAG R/A, MEHEDIBAGI CHITTAGONG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AT NASIRABAD, CHITTAGONG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GRAMEEN LEPTIS MAGNA</td>
<td>GRAMEEN BANGLA HOUSING LTD</td>
<td>3000 psi</td>
<td>60000 psi</td>
</tr>
<tr>
<td>9 STORIED APARTMENT BUILDING</td>
<td>SONARTORI TOWER (7TH FLOOR), 12 SONAR GAON ROAD, DHAKA 1000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WELKIN'S CALYX</td>
<td>WELKIN'S PROPERTY MANAGEMENT LTD</td>
<td>2500 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>9 STORIED APARTMENT BUILDING</td>
<td>43/D, AMIRBAG R/A, MEHEDIBAGI CHITTAGONG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AT NASIRABAD, CHITTAGONG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GRAMEEN LEPTIS MAGNA</td>
<td>GRAMEEN BANGLA HOUSING LTD</td>
<td>3000 psi</td>
<td>60000 psi</td>
</tr>
<tr>
<td>9 STORIED APARTMENT BUILDING</td>
<td>SONARTORI TOWER (7TH FLOOR), 12 SONAR GAON ROAD, DHAKA 1000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-STORIED OFFICE BUILDING AT KUTURIA, SAVAR, DHAKA</td>
<td>RUNNER AUTOMOBILES LTD 74/B, GREEN ROAD DHAKA</td>
<td>2500 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>5-STORIED RESIDENTIAL BUILDING FOR MR. ROBIUL KARIM AT PLOT NO-1/B, ROAD NO - 7, SECTOR - 7, UTARA MODEL TOWN, DHAKA</td>
<td>MR. ROBIUL KARIM</td>
<td>2500 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>SNIGHDA ORCHID ROAD NO - 5, HOUSE NO - 7, BLOCK - 1, BANANI, DHAKA</td>
<td>UNITECH HOLDINGS LIMITED</td>
<td>2500 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>JALCHYA ROAD NO - 9, HOUSE NO - 35, SECTOR - 4, UTTARA, DHAKA</td>
<td>UNITECH HOLDINGS LIMITED</td>
<td>2500 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>ROUDRACHYA ROAD NO - 9, HOUSE NO - 31, SECTOR - 4, UTTARA, DHAKA</td>
<td>UNITECH HOLDINGS LIMITED</td>
<td>2500 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>UNITECH PRESIDENCY HUMAYAN ROAD, PLOT NO 34, MOHAMMADPUR, DHAKA</td>
<td>UNITECH HOLDINGS LIMITED</td>
<td>2500 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>6-STORIED RESIDENTIAL BUILDING FOR MD TOFAZZEL HOSSAIN, PLOT NO-64, BLOCK - C, MANSURABAD HOUSING SOCIETY, MOHAMMADPUR, DHAKA</td>
<td>MD TOFAZZEL HOSSAIN</td>
<td>2500 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>8-STORIED 1X16 MARRIED ORS QUARTER AT SHAHEED YOUSUF ROAD, DHAKA CANTT</td>
<td>OFFICE OF THE DW &amp; CE (ARMY) DHAKA CANTT</td>
<td>3000 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>8-STORIED 1X16 MARRIED ORS QUARTER AT POSTOCOLA CANTT, DHAKA</td>
<td>OFFICE OF THE DW &amp; CE (ARMY) DHAKA CANTT</td>
<td>3000 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>8-STORIED 1X16 MARRIED ORS QUARTER AT ARMY HEAD QUATER ADMIN WING, DHAKA CANTT</td>
<td>OFFICE OF THE DW &amp; CE (ARMY) DHAKA CANTT</td>
<td>3000 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>4-STORIED ENGINEERING FACILITIES BUILDING, JMBAR PROJECT, SARAK BHABAN, RBD</td>
<td></td>
<td>3000 psi</td>
<td>60000 psi</td>
</tr>
<tr>
<td>RAMNA, DHAKA</td>
<td>SHAFTAK SHAHNAMA</td>
<td>SHAFTAK GRIHAYAN LIMITED</td>
<td>3000 psi</td>
</tr>
<tr>
<td>--------------</td>
<td>------------------</td>
<td>--------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>8 (EIGHT) STORIED APARTMENT BUILDING FOR MR. M. MOSHIUR RAHMAN AT PLOT NO. 3/4, BLOCK-C, LALMATIA, DHAKA - 1207</td>
<td>8/19 BLOCK-C, LALMATIA, DHAKA - 1207</td>
<td>3000 psi</td>
<td>40000 psi</td>
</tr>
<tr>
<td>SHAFTAK MAVIS</td>
<td>8 (EIGHT) STORIED APARTMENT BUILDING FOR MR. M. MOSHIUR RAHMAN AT PLOT NO. 3/4, BLOCK-C, LALMATIA, DHAKA - 1207</td>
<td>SHAFTAK GRIHAYAN LIMITED</td>
<td>8/19 BLOCK-C, LALMATIA, DHAKA - 1207</td>
</tr>
</tbody>
</table>
APPENDIX-C

List of Buildings, Using Excavator/Labour for Excavation Work
<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>DEVELOPER</th>
<th>NO OF BASEMENT</th>
<th>EXCAVATION WORK PERFORMED BY</th>
</tr>
</thead>
<tbody>
<tr>
<td>LABAID CARDIAC CENTRE, ROAD - 4, DHANMONDI, DHAKA</td>
<td>LAB AID CONSTRUCTION</td>
<td>2</td>
<td>EQUIPMENT INTENSIVE</td>
</tr>
<tr>
<td>LABAID SPECIALIZED HOSPITAL, ROAD - 4, DHANMONDI, DHAKA</td>
<td>LAB AID CONSTRUCTION</td>
<td>2</td>
<td>EQUIPMENT INTENSIVE</td>
</tr>
<tr>
<td>HABITAT CENTER 21 STORIED SHOPPING OFFICE COMPLEX SHYAMOLI, DHAKA</td>
<td>HABITAT REAL ESTATE LTD</td>
<td>2</td>
<td>EQUIPMENT INTENSIVE</td>
</tr>
<tr>
<td>SAM COMPLEX 21 STORIED SHOPPING OFFICE COMPLEX SHYAMOLI, DHAKA</td>
<td>GLOBE CENTER LTD.</td>
<td>2</td>
<td>EQUIPMENT INTENSIVE</td>
</tr>
<tr>
<td>GLOBE SHOPING CENTER 10 STORIED SHOPPING OFFICE COMPLEX 24 MIRPUR ROAD DHAKA</td>
<td>HAPPY HOMES LTD</td>
<td>2</td>
<td>EQUIPMENT INTENSIVE</td>
</tr>
<tr>
<td>HAPPY HOMES DR RAFATULLA ARCADE 6 STORIED BUILDING ROAD NO 3, DHANMONDI, DHAKA</td>
<td>HAPPY HOMES LTD</td>
<td>2</td>
<td>EQUIPMENT INTENSIVE</td>
</tr>
<tr>
<td>MULTIPLAN GREEN VILLA 15 STORIED BUILDING GREEN ROAD, DHAKA</td>
<td>MULTIPLAN LTD.</td>
<td>2</td>
<td>LABOUR INTENSIVE</td>
</tr>
<tr>
<td>Such as 18 Storied New Market City Complex adjacent of Dhaka new market</td>
<td>UNIVERSE CONSTRUCTION LTD (CONTRACTOR)</td>
<td>2</td>
<td>LABOUR INTENSIVE</td>
</tr>
<tr>
<td>14 storied CRP building project at Mirpur-14, Dhaka.</td>
<td>CRP</td>
<td>2</td>
<td>LABOUR INTENSIVE</td>
</tr>
</tbody>
</table>